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FINAL REPORT

MINIATURE DATA RECORDER  
WITH PLAYBACK UNIT

PROJECT #112

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INSTRUCTION MANUAL - SORENSEN FCR-100  
With Modification made by

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FINAL    REPORT

MINIATURE    DATA    RECORDER

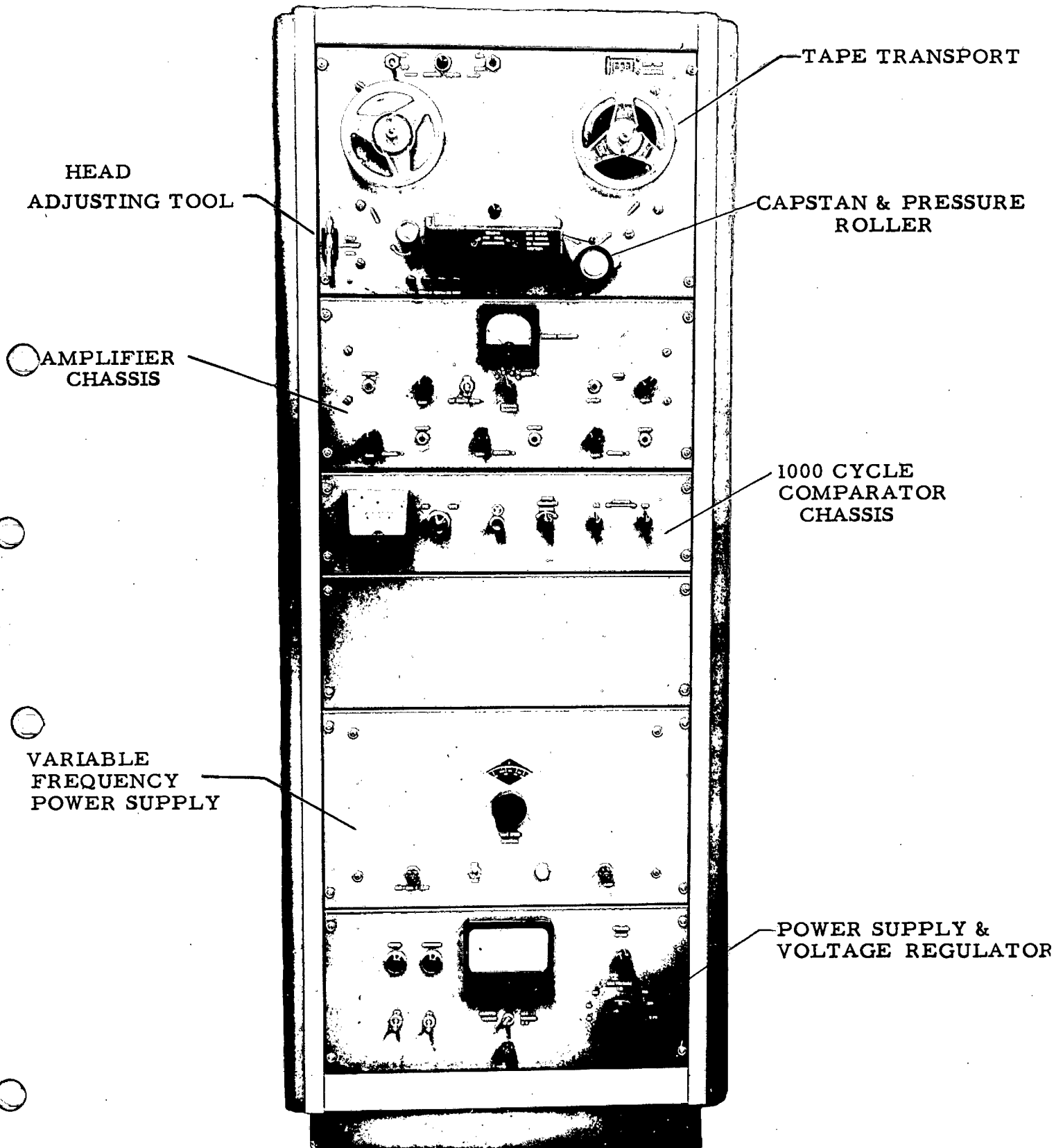
WITH    PLAYBACK    UNIT

This report covers all development and design data on this project in accordance with specification No. 57-A-1059-A and changes to specification No. 57-A-1059-A dated 17 March 1958.

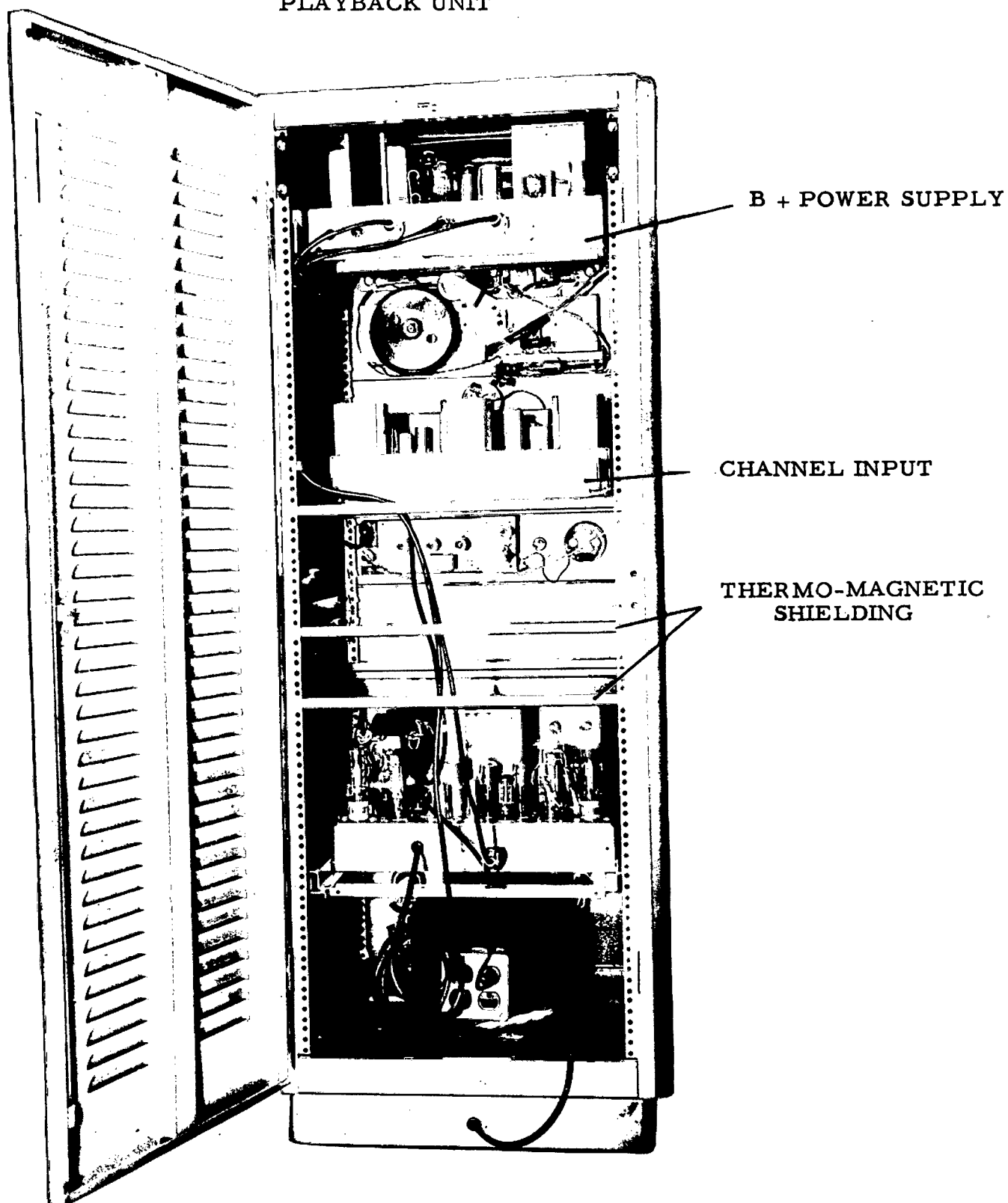
On 28 October 1958 the playback unit was delivered and on 1 November 1958 the Miniature Data Recorder was delivered. This report will describe these units as well as their development history and maintenance and operation manuals.

In the appendage are the operating instructions for the repaired Playback Unit.

P L A Y B A C K   U N I T



BACK OF  
PLAYBACK UNIT



1. Contract Specifications

1.1 The specification No. 57-A-1059-A describes a miniaturized magnetic tape recorder and its associated playback unit. This recorder is to be used in conjunction with other devices which will furnish recordable data. The purpose of the recorder is to permit an accurate identification and correlation of the recorded events.

1.2 The tape recorder shall be miniaturized for hand operation. It shall be no larger than 5 inches by 3 inches by 1-1/2 inches. It shall be capable of simultaneously recording three parallel channels on 1/4 inch recording tape continuously for 60 minutes. Two of the channels shall be arranged to record incoming data signals, while the third shall be reserved for voice announcement or tape speed reference tone. All of the recorder electronics shall be contained internally.

1.3 The playback unit shall be a rack-mounted device capable of faithfully reproducing the data signals at the recorded speed.

1.4 Further technical specifications can be found in specification No. 57-A-1059-A dated 4 February 1957.

2. Deviation From Specification

2.1 Any deviation from the specification is covered in the development section of this report. In general, there are few deviations, as the model delivered was an engineering model and designed to conform to or approach the specification.

### 3. Historical Development

3.1 The following section will summarize the development history for the duration of the project. Various technical details and test results of the various components can be found in the bi-monthly reports.

3.1.1 After fully analyzing and testing various design approaches of tape transport systems, the magazine loaded, friction driven tape transport was selected. A few of the advantages of this system over the co-axial, belt-driven opposed reel or gear driven magazine loaded unit are as follows:

3.1.1.1 The tape track requires less power to drive than the co-axial or opposed reel designs. The co-axial tape track had to include tape guides to transfer the tape from one reel plane to another. The added components and friction of the tape guides demanded more torque transmitted by the capstan and pressure roller and also complicated the tape track for threading. The opposed reel design again required excessive torque due to the high belt tension required to transmit torque to the reels. The worm and worm wheel in the gear driven unit produced high frequency flutter and prevented the use of a flywheel because of the configuration of the components. The friction driven unit consists of a .562 inch diameter rubber roller engaged with the .098 inch diameter motor shaft. From the roller shaft, a pulley drives a 1.250 inch diameter flywheel constructed of tungsten and mounted on the capstan shaft. Tests indicated that this drive system has better constant speed characteristics than other drives considered for this project.

3.1.1.2 A PM motor, produced by Cramer Controls Corporation, is used as the power source for the drive mechanism. Of the motors tested and investigated, the Cramer motor has more desirable qualities than the others. A list of these qualities is as follows:

3.1.1.2.1 An internal governor regulating the motor speed within two percent.

3.1.1.2.2 Ball bearing construction providing reliable operation.

3.1.1.2.3 Acceptable current drain of 150 milliamperes.

3.1.1.2.4 Low audible noise level.

3.1.1.3 The primary disadvantage with this motor, or any PM motor is the problem of suppression of the motor noise radiated by the governor contacts and armature flux. The governor switch interrupts the full armature current in the unmodified state. This action of the governor produces wide-band noise radiation by arcing when opening and produces a key click effect when closing due to the high positive rate of change of armature current. The armature flux is propagated radially from the motor in all directions and produces a whine, in the audio range, of relatively constant pitch. The elimination and suppression of motor noise is covered in detail in the bi-monthly report dated 21 July 1958.

3.1.1.4 The motor shaft engages the rubber rimmed drive roller as the first phase in speed reduction of the friction drive. By having the drive roller shaft bearing mounts an integral part of the motor frame, closer tolerances are maintained and speed variations are reduced. A special molded rubber belt transmits the drive to the flywheel. Because of the low velocity and small radius of the flywheel, it was constructed of heavy metal.



The particular alloy, chosen for weight and machinability, is Fansteel No. 77-BL-2 Tungsten. The high compliancy of the rubber belt and the energy produced by the flywheel tend to reduce wow and flutter caused by motor speed variations and drive system irregularities.

3.1.2 Various tests were conducted, for constant speed characteristics, to determine a suitable drive system. To further isolate speed variations on the selected drive, the unit was tested by recording a tape and playing back on the playback unit. By measuring the wow and flutter frequency, speed variations could be isolated to a particular shaft or component in the recorder. For example, a flutter frequency of 20 cps would mean speed variations caused by the rubber drive roller which revolved at 20 RPS. To eliminate any additional wow and flutter, such as that contributed by the playback unit, the recorder was used as a playback unit with a pre-recorded accurate tape of 3 KC. From the results of this test, it was found that the recorder had wow and flutter of 2.5 percent peak to peak or a .88 percent RMS at 3 KC and 1-7/8 inches per second tape speed. The wow and flutter of the system, recorded on the miniature recorder and played back on the playback unit, was 1.06 percent RMS at 3 KC and 1-7/8 inches per second tape speed.

3.1.3 Several recording and playback heads were constructed by

[redacted] During this period, design changes were incorporated for ease of assembly and increase in efficiency.

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3.1.3.1 Brass was used for the first magnetic heads built by [redacted]

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[redacted] Because it has a higher coefficient of expansion than steel, and being softer material does not lap as well as steel, the core support material was changed to 303 stainless steel. The stainless was annealed

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after machining the pole piece mounting grooves to stabilize it. If this material is cold worked, however, it will become slightly magnetic.

3.1.3.2 Exotic materials such as Supermalloy, Permalloy, Mu-metal and all exceptionally high permeability materials are very sensitive to mechanical stress. In the first magnetic head design, Mu-metal was used as a pole material and had a cross sectional area of .012 x .040. The pole pieces were pressed in place in grooves and the material was upset on either side of the grooves to retain them. \*Supermalloy, one of the highest permeability materials was used in another recording head. It can only be procured from [redacted] and must be annealed by them. Because of the sensitivity to mechanical stress, the method of application of the pole pieces to the head core was changed to bonding the pole pieces in place instead of upsetting the material on each side of the groove. To still retain the pole pieces securely against the bottom of the groove, it was decided to make the grooves deeper and fill the area of the groove, remaining after locating the pole pieces, with an epoxy called S. A. M. which set very hard after curing at about 100°F. To expose the gap, the O. D. was ground and lapped .100 inch off center, enough epoxy remained in the majority of the groove to retain the pole pieces.

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3.1.3.2.1 Eastman 910 Adhesive was used for bonding the mylar tape to the pole pieces and securing the leads after winding. Experiments were conducted using R-314 (S. A. M. ), Epon Z-28, Laminac #4116 and Eastman 910 for cementing the pole pieces securely in place. R-314 (S. A. M. ), used by [redacted] for securing the hairspring, was selected. A 20% hardener A type was used for curing at 100°F.

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3.1.3.3 [ ] used 60 turns of #40 wire (.0035 to .004 dia.) in the first design. The first head fabricated at [ ] used the same arrangement. In the second head, the wire size was changed to 120 turns of #43 wire (.0023 to .0025 dia.).

To prevent breaking the magnet wire leads, (.0022 dia.), teflon coated stranded wire was soldered to the Celenamel and set in epoxy near the end of the core. Each lead is insulated after soldering with Eastman cement or equivalent.

3.1.3.4 To achieve the degree of accuracy necessary to obtain a 0.000020 gap between two core halves, the mating surfaces had to be ground to a 2 to 3 R. M. S. finish and to about 1/3 of a light band (0.000004) in flatness. This was accomplished on a Crane lapmaster using Aluminum oxide grit #1900. A leaded precision lap plate charged with #1700 grit was used to obtain higher reflectivity and remove the grit. A master optical flat and a mono-chromatic light was used for checking this work. A profilometer was used to check the R. M. S. value.

3.1.3.5 To provide a gap of a definite value, gold leaf was originally employed. One of the problems encountered in the application of gold leaf was keeping it from overlapping and separating. Also, it is electro-static and difficult to apply. Investigation was started to learn if plating a non-magnetic gap might be feasible. A uniform thickness in micro-inches would be hard to attain in plating. A deposition of aluminum or gold in an evacuated area could be used to provide a uniform thickness. To accomplish a deposition of 0.000010 aluminum uniformly distributed over area of head core, certain controls and considerations were necessary.

Material - Aluminum pure

Length = .600

Thickness = .003

Width = .117

Evacuated pressure -

.2 Micron\*

Use one electrode directly in line, no tree turning.

Electrode - Tungsten wire - (special for metalizing).

To measure the deposition, a Johanson block ground to .000004 in flatness was used. One-half of the block was masked and the increase in size was measured on a comparator (Lietz) or Swedish gage.

3.1.3.6 One of the most critical operations in fabricating a head is the assembly of the two core sections. Cleanliness is essential, any dust or particles of dirt, or foreign matter can increase the gap. The head must be assembled in a controlled, dust-free atmosphere and under a microscope. The fitting of the dowels must be checked to ascertain they do not interfere with the wires and that the holes are clean to the proper depth. 80 pounds of air pressure has to be applied to be sure that any air trapped between the head surfaces will escape. At this point or before cementing, a microscope could read the gap before cementing. Following this procedure, there would be an opportunity to take the head apart and correct any errors that were observed in gap width or surface finish.

3.1.3.7 Lapping of the record head O. D. must be accomplished. Diamond was selected as the cutting material because it will cut with a small amount of pressure or friction. It is necessary to use a fairly hard material charged with 0 to 2 micron diamond. (Copper or linen base phenolic). The first

heads were designed cylindrical to alleviate the lapping problems. Later it became necessary to lap off center when it was decided to bond the pole pieces in place. A special fixture was made for this purpose and a 2 micro-inch (R. M. S. ) finish was obtained.

Centerless grinding or lapping produces fine steps that show up under high magnification.

3.1.3.8 A tabulation of the various recording and playback heads constructed is illustrated as Figure 1.

3.1.4 The choice of microphones was for a low impedance high output microphone. These microphones are found in the hearing aid industry. Figure 2 shows the frequency response of both the internal model #1375 and external model #1382 microphone. These controlled reluctance microphones are well adapted to operate into transistor impedance range and can operate in the range of temperature of -30 degrees C to 50 degrees C without appreciable degrading. For the ratio of per unit volume to output, these controlled reluctance microphones gave the highest figure. Since all the ribbon, dynamic and Rochelle salts microphone are temperature sensitive, the ceramic crystal could be used, but the output would greatly suffer working into low impedance source and a considerably reduced diaphragm.

3.1.5 The electronics circuitry consists of two data amplifiers, one audio amplifier, and a 1000 cps oscillator with their associated terminal and interconnecting system. These circuits are shown schematically in Figure 3. Characteristics of the amplifiers are given in the  Report.

Physically, the amplifiers and oscillator are built with miniature components mounted on etched circuit boards.

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3.1.5.1 The 1000 cps oscillator consists of a 1 KC quartz crystal in a circuit employing two silicon transistors and a miniature LC circuit shown in Figure 4. Crystal control was chosen because of the favorable volume stability ratio. Mechanical oscillators (tuning forks) were available with higher orders of accuracy than the crystal unit. Self-excited electronic oscillators could be reduced to a package size considerably smaller than the crystal unit used. But the crystal appeared to offer the best compromise between size and frequency stability. (Temperature control achieved through tuning coil with bi-metallic disc). Figure 5 shows the performance of this oscillator at various temperatures and voltages. In a voltage range of 4.5 to 7.5 and a temperature range of - 30 degrees C to + 50 degrees C, the maximum deviation from 1000 cps was 24 parts in 100,000. Total current consumption over the same temperature and voltage ranges varied from 1.6 to 3 ma. The output is isolated from the transistor D. C. by C14. R31 and R32 provide two outputs with load limiting---that is, either or both outputs could be short-circuited without loading the oscillator to a point which would impair its operation.

#### 4. Engineering Model

4.1 The following paragraphs can be used as operating instructions for the Miniature Recorder.

4.1.1 Preparation of Recorder - Remove (2) #2-56 flat head screws in cover. Remove (4) #2-56 socket head cap screws holding waterproof cover on controls. For diagram of controls, see Figure A, and CMI12-01. For wiring diagram of engineering model of the recorder, see Figure 3.

4.1.2 Tape loading and threading - When mounting the tape magazine, disengage the pressure roller using the recess in the pressure roller bracket (Item 1). Align the drive pins on the take-up shaft with the two holes in the take-up hub of the magazine. Thread tape as shown in Item 2.

CAUTION: Be sure tape is in guide grooves on the record head and contacting the surface of the pole pieces of the head. Release pressure roller and record head pressure pad by moving pressure roller release button to the left. (Item 3) If tape does not track properly, disengage and engage pressure roller again while the recorder motor is running.

4.1.3 Operation and Controls - By turning the control switch to the ON position, the recorder amplifiers and the 1 KC oscillator will be on. By turning to the RECORD position, the recorder motor will be turned on with the amplifiers remaining on. With no other connections, the recorder would be recording a 1 KC signal and signals received on the internal microphone.

4.1.3.1 When the 1000 cps out jack is utilized, the 1 KC tone normally being recorded internally would be broken. This would permit the 1 KC out to be modulated by another unit and then recorded by plugging back in the external microphone jack.

4.1.3.2 The external power plug and cable are supplied. The positive lead for both circuit and motor batteries is common.

4.1.3.3 The external switch plug and cable are supplied. A two pole, three position switch would be required for operation of the recorder through this jack. If the external switch is to be used, the control switch on the recorder must be in the OFF position.

4.1.3.4 The two Subminax co-axial connectors are for the two data channel inputs. The selector switch to the left of the connectors selects which channel to be monitored through the earphone.

The clockwise position of the switch is for channel 2, counter clockwise for channel 1.

4.1.3.5 The batteries in the engineering model of the recorder are as follows:

Motor Batteries - 5 #RM-1 Mallory Mercury Cells

Circuit Batteries - 5 #RM-125 Mallory Mercury Cells

The batteries must be tested to Mallory specification (100 MA load - 1.1V per cell) to provide the running time of approximately two hours for the motor and 10 hours for the circuits. In the event a longer running time is desired with internal power, a small extension for the battery compartment is supplied. Using this extension 5 #RM-601-R Mallory cells are used. This will provide approximately 7 hours of running time, with the circuit batteries remaining the same.

4.2 Whenever possible, disengage the pressure roller from the capstan shaft. External power should be 6V D. C. Current drain will be approximately 150 MA on the motor circuit and 12 MA on the amplifier circuit.

4.3 When reloading tape magazine, be sure both hubs are free to turn before mounting on recorder. Recording tape is secured to hub by tape. Make the first few turns on take-up hub by hand after securing tape.

4.4 The jumper across R36 provides for maximum coupling of the 1000 -cycle oscillator signal to the audio amplifier. The coupling can be reduced by removing this jumper and substitution of a suitable resistor in the place of R36. With the jumper and R36 both removed, the 1000-cycle signal is reduced to a minimum level due to stray field coupling.



When a plug is inserted into the 1 KC output jack, direct coupling to the audio amplifier is broken. The residual low-level 1 KC signal in the amplifier is due to stray field coupling.

4.5 When replacing batteries, polarity as shown in Figure 3 must be observed. Insulation of cells in battery compartments must be preserved.

4.6 Items supplied with recorder:

- 1 - M112 Recorder - CB-3
- 1 - Recorder Carrying Case
- 1 - External Microphone
- 2 - Subminax Cables - (Data Channels)
- 1 - External power cable
- 1 - External Switch cable
- 1 - Co-axial cable (1000 cps out)
- 2 - Extra cables
- 1 - Earphone and cable
- 6 - Mallory RM-125 mercury cells
- 20 - Mallory RM-1 mercury cells
- 10 - Mallory RM-601-R mercury cells
- 1 - External battery extension

5. Development History

5.1 The Playback is a self-contained unit in a single cabinet and with slight modification can be made to record as well as playback. It operates from a voltage source of 40 to 65 cps with input voltages of 70, 95, 120, 150, 190, 230, and 270 volts. The voltage can be adjusted by means of a stepping switch in conjunction with a rheostat and panel meter. A range switch is provided with the meter to read directly or X2. Figure 6 is the circuit diagram. Figure 7 is a block diagram of the Playback Unit.

5.2 Since the source frequency may vary from 40 to 65 cps, the capstan on the transport mechanism is driven from a 2-phase motor with a separate frequency controlled power source. Model FCR-100 Sorensen power oscillator, with a slight modification, can be varied over a wide range of frequencies resulting in a continuously variable tape speed control. The tape speed can be manually adjusted from the control panel over a range from 1.0 ips to 3.5 ips. Since a 2-phase motor is used, a reasonably correct value of capacitance is needed. Table I gives the correct capacitor setting for each tape speed. A precaution - wow and flutter will increase if incorrect capacitance is used. The frequency selector switch was removed to prevent accidentally switching to the high frequency. The output knob is turned completely clockwise for maximum output voltage and is not necessary to adjust for the tape speed changes. The capstan motor will operate from 45 to 150 cps with no adjustments necessary except for the proper setting of the capacitance knob. The voltage across the motor can be measured at the output terminals of the power oscillator. The Capstan Motor Oscillator produces an excellent wave form with practically no harmonics nor can any frequency drift be detected.

5.2.1 Due to the excessive heat and A. C. hum, the oscillator had to be located in a well ventilated area and physically removed as far as possible from the tape head and amplifier inputs. To dissipate the heat, a fan was installed on the rear door.

5.2.2 To operate the motor, the equipment switch must be turned on, then the power switch of the oscillator and 30 seconds later, the power output switch.

### 5.3 Tape Transport

The tape transport mechanism was selected for the system for its dynamic braking, which is preferred in handling extra thin tapes. The original tape

drive was removed and a tighter tolerance motor, larger idler pulley and heavier flywheel was installed on a 1/4 inch steel plate to minimize any relative motion between the motor, idler and flywheel.

5.3.1 The counter on the transport merely counts numbers and is only indicative of tape length. The idler roller must always be removed from contact with the flywheel when not in use. The pointer knob removes the contact and extinguishes the neon indicator.

5.3.2 The tape wrap around the head is ample and is possible to use without the pressure pad, but the use of a slight pressure from the pad has a tendency to keep the vicinity of the air gap clean and give a better high frequency response. The pressure pad and tape must never be in contact with the head for fast forward or rewind.

5.3.3 The wow and flutter was measured with a Furst Electronics 3 KC Model 115-R Wow and Meter and found to be 0.4 to 0.8% peak. An RCA, 3 KC 0.1% rms was used to check the wow.

5.3.4 The capstan should occasionally be cleaned with alcohol and wiped dry. The capstan bearings need very little oiling and the capstan shaft should at all times be kept bone dry. Figure 8 is the circuit diagram.

#### 5.4 Tape Speed Indicator

During playback, the tape speed is adjusted to correspond to the recorded tape speed. This is accomplished by comparing the 1 KC reference signal recorded on the tape with a 1 KC reference signal built into the playback system. Two indicators are employed for determining the proper tape speed. First, a meter is used in conjunction with a frequency sensitive circuit to indicate whether or not the recorded 1 KC reference signal being played back is high or low, thereby indicating that the speed is either fast or slow. The tape speed

can then be manually adjusted to correct the difference indicated. The second indicator is used when the meter indicator shows that the tape speed is nearly correct. A neon bulb indicator flashes the difference beat of the two referenced frequencies. As the tape speed is finally adjusted, the beat frequency is reduced to zero. Due to the wow and flutter introduced during recording and playback, the neon indicator never actually reaches a nulled state. The rate of flashes due to the wow and flutter are low in frequency and occur more or less randomly. More rapid repetitive flashes result from the tape speed being slightly fast or slow, giving a definite periodic beat frequency between the two reference signals. Figure 9 is the circuit diagram of the speed indicator just described. Figure 10 is the circuit diagram of the 1 KC tuning fork oscillator used in the Playback Unit for reference.

#### 5.5 Playback Amplifier

The head winding of each track is connected to an amplifier. The two data amplifiers are identical. Equalization is employed to obtain an output frequency response of the overall record playback system of  $\pm 3$  db from 250 cps to 10 KC. The third channel has equalization for the voice channel and is cut off at 4 KC to reduce the noise level. Figure 11 is the circuit diagram of the three amplifiers and auxiliary output. An input transformer is used with each amplifier to attain an input level suitable for a vacuum tube amplifier. Equalization is applied in a feedback circuit between the third and fifth stages of each amplifier. Figure 12 is the frequency response of the audio and data playback amplifiers. The audio amplifier contains a 1 KC reject filter when in use at all times except when it is desirable to listen to the 1 KC test signal on the tape.

5.5.1 The input impedance of the playback amplifiers is approximately 10 ohms and will not overload at 50 microvolts input or less. At full gain setting,

the last stage of the amplifier will distort if the input signal exceeds three microvolts. The gain control is on the grid of the last stage. When not in use, the amplifiers are always terminated into a 600 load which is removed when a phone plug is inserted into the jack.

5.5.2 The output can be received at the head phone plug and along with the VU meter can be read or heard. A phone jack on top of the audio chassis is used to make connection to the speed indicator to obtain the recorded 1 KC. The back of the chassis contains all the connections for tape head and power inputs with keyed connectors.

#### 5.6 High Voltage D. C. Supply

A Dressen-Barns regulated power supply is the DC source for the amplifier. Figure 13 is the circuit diagram for the power supply. To minimize amplifier noise, D. C. voltage is used on the first two tubes filaments of each amplifier. Figure shows the circuit employing a full wave selenium rectifier type battery charger and with a pi filter.

5.7 The many problems of the tape heads construction is reported elsewhere in this report. A number of magnetic heads were constructed which could be used in both the recorder and playback unit. Figures 14 and 15 show the frequency response of the record head with and without equalization. Since all three channels gave identical response and output, the selection of channels was made on the playback unit.

5.7.1 Figures 16 and 17 shows the frequency response of the playback head with and without equalization. A choice of channels had to be made. In the audio playback, the frequency is intentionally cutoff at 4 KC, the bottom channel was the natural choice as can be seen from the frequency response curve. The audio output would not suffer appreciably, and this channel gave the highest

out at 1 DC, approximately 12 microvolts. The best or top channel went to the channel 3 and middle channel to channel 2.

5.7.2 Figures 18 and 19 shows the frequency response of a head constructed by an outside source, with and without equalization. While the curves have a little flatter response, they still did not meet the specification nor were there three complete channels. The middle channel unknownly became shorted.

5.7.3 Figure 20 shows the record-playback of a 5, 50, 500, 5000 micro-second pulse with a repetition rate of 1000. Due to the wow and flutter it gives blurred images on the oscilloscope. The pulse can easily be seen on a single sweep.

## 6. Operation Instructions

6.1 Observing the cabinet from the front and starting at the top, you will observe five separate chassis and a drawer.

6.1.1 A three-channel high gain amplifier with a 1 KC reject filter in Channel #1. The three channels can be received simultaneous in the mixer output.

6.1.2 A tape transport.

6.1.3 A tape speed indicator.

6.1.4 A power oscillator to drive the variable speed motor.

6.1.5 An auto-transformer with voltage adjustment.

6.1.6 Figure 7 shows a block diagram which also includes the B voltage and D. C. filament supply for the amplifier. This chassis is located behind the tape deck inside of the cabinet.

6.1.7 Figure 6 is a line diagram of the power supply. A stepped transformer is employed so that the system can be operated from a variety of A. C. power sources. Since the source frequency may vary from 40 to 65 cycles per second cps, the capstan on the transport mechanism is driven from a separate

frequency controlled power source. The frequency of the Sorensen oscillator power amplifier can be varied over a wide range of frequencies, resulting in a continuously variable tape speed control. The tape speed can be manually adjusted from the control panel over a range of from 1 to 3-1/2 ips. Several parts of the playback system are modified commercial components.

## 6.2 Operating Procedure

6.2.1 Close power switch on bottom panel and adjust voltage with both the course and fine knob.

6.2.2 Turn equipment switch on.

6.2.3 Turn power switch of the power oscillator on.

6.2.4 Turn output power switch on and adjust output voltage (upper left of dial to 115 V A. C. measured at the output jacks of the power oscillator.

6.2.5 Turn pointer knob of tape transport and red neon glows (engages idler roller to brass flywheel).

NOTE: If capstan does not rotate turn capacitor switch one complete revolution (knob with decal numbers on power oscillator) improper setting of capacitor knob can increase wow and flutter.

6.2.6 Switch on 1 KC reject filter.

6.2.7 Place the tape to be played on the left hand spindle of the transport and thread tape under the first tape guide, and over tape head.

Caution: Do not let the tape contact the permanent magnet just above the tape guide) between capstan and pressure roller to take up reel. Figure 8 shows the wiring of the transport panel.

6.2.8 Depress the button type switch on the transport panel marked "run " to engage capstan.

6.2.9 Adjust pressure pad above head for minimum pressure.

6.2.10 Output can be obtained from any output jack, regardless of output switch setting. (The switch is for the headphones and meter only.)

- 6.2.11 CAUTION: Do not under any circumstance for any length of time, allow the tape to be in contact with the head for rewind or fast forward. The tape must be lifted from the head and a pencil or other material should be between head and tape.

Standard servicing practice should be used on all the electronic equipment.

Periodic checks of the system's performance should be made. Periodic checks of all moving parts should also be made, oiling as is found necessary.

### 6.3 Operating Procedure for Speed Adjustment

- 6.3.1 Place the tape to be played back on the left hand spindle of the tape transport, and attach the end of the tape to the take-up reel after threading through the head.
- 6.3.2 Null the comparator meter by adjusting the D. C. balance control. This does not need frequent adjustment.
- 6.3.3 Press the red button on the speed control panel and null the comparator meter by adjusting the 1000 cps balance control. Then release the button.
- 6.3.4 Depress the run button on the switch on the transport unit to engage the capstan.
- 6.3.5 Switch off the 1 KC reject filter to "Off".
- 6.3.6 Using earphone, connect to the audio channel output, listen for the 1000 cps tone.
- 6.3.7 When it is audible, adjust speed controls so that both halves of the neon indicator glow with the same intensity.
- 6.3.8 Observe meter indicator. If it indicates that tape speed is either fast or slow, adjust tape speed control to null the comparator meter. The tape speed is continuously variable, the upper scale on the dial



reading in inches per second (approximately) and the lower scale in frequency of the driver oscillator.

- 6.3.9 When the meter is between the parallel lines, then observe the neon indicator and adjust the speed control to decrease the beat rate to a minimum. As indicated before, wow and flutter introduced by the recorder and playback unit makes it impossible to reduce the beat rate of the neon indicator to zero. When this condition is reached, the playback tape speed has its best adjustment, and is the same as that used during recording. No further adjustment of speed is necessary unless the recorder speed changes. In that event, the change will be indicated by the two playback speed indicators. Figure 9 shows the speed indicator circuits. Figure 4 is the circuit diagram of the 1000-cycle per second tuning fork oscillator used in the playback unit for reference.

#### 6.4 Additional Information

- 6.4.1 A 600 ohm load is always connected to the output jacks, but is removed when a phone plug is inserted.
- 6.4.2 The VU meter does not handle the maximum output of the amplifier, therefore, although this meter may be off scale, it does not necessarily mean that the output signal is distorted.
- 6.4.3 The playback head can be adjusted for head tracking by the screws in back and sides of the head mounting block. Since the recorder signal length can be as low as 10 millionths, this adjustment can become quite critical.
- 6.4.4 If capstan does not rotate with power applied, rotate the capacitor switch one complete revolution. NOTE: The capacitor switch is the knob with the decal numbers on the left side of the Sorensen oscillator amplifier. Table I gives the approximate setting for

different tape speeds. Improper setting of capacitor knob can increase wow and flutter.

- 6.4.5 The head winding of each track is connected to an amplifier. The two data amplifiers are identical. Equalization is employed to obtain an output frequency response of the overall record playback system of  $\pm 3$  db from 250 cps to 10 KC. The third channel has equalization for the voice channel, and is cut off at 4 KC so that the noise level is reduced. Figure 11 is a diagram of the three amplifiers and auxiliary outputs as called for in the specification. An input transformer is used with each amplifier to attain an input level suitable for the vacuum tube amplifier. Equalization is applied in the feedback circuit between the fifth and third stages of each amplifier. A maximum output level of approximately three volts rms across 600 ohms is possible from a recording made with one milliamperere.
- 6.4.6 A separate output stage is provided for combining signals of all three amplifiers. Also an output is provided for earphones which can be switched to any one of the three outputs. A VU meter is combined in this circuit for measurement of the playback signal level.
- 6.4.7 A Dressen-Barns power supply is the D. C. power source for the amplifier unit. Figure 13 is a circuit diagram for the Dressen-Barns power supply. In order to minimize the hum pick-up D. C. voltage is used on the tube filaments. Figure 13A shows the circuit employing the full wave selenium rectifier type battery charger. Both the B supply and D. C. filament supply are mounted on the same chassis.

6. 4. 8 An erasing magnet is positioned to the left of the head and can be put into place with the red knob for recording on the playback unit.

CAUTION: When treading, do not allow the tape in contact with the magnet.

6. 4. 9 Output can be obtained from any of the input jacks regardless of output switch setting. The switch merely switches the head phones and meter to the desired channel.

TABLE I

<u>Switch Setting</u>	<u>in/sec</u>	<u>C/mfd</u>	<u>cps</u>
=	4.0	0.5	160
0	3.5	0.75	140
1	3.0	1.0	125
2	2.4	1.3	100
3	2.2	1.5	90
4	1.9	1.7	80
5	1.8	2.0	75
6	1.7	2.2	70
7	1.6	2.5	65
8	1.4	2.7	60
9	1.2	3.0	50
10	1.0	5.0	40

Oscillator frequency vs in/sec tape speed

$S_t$  = tape speed in/sec

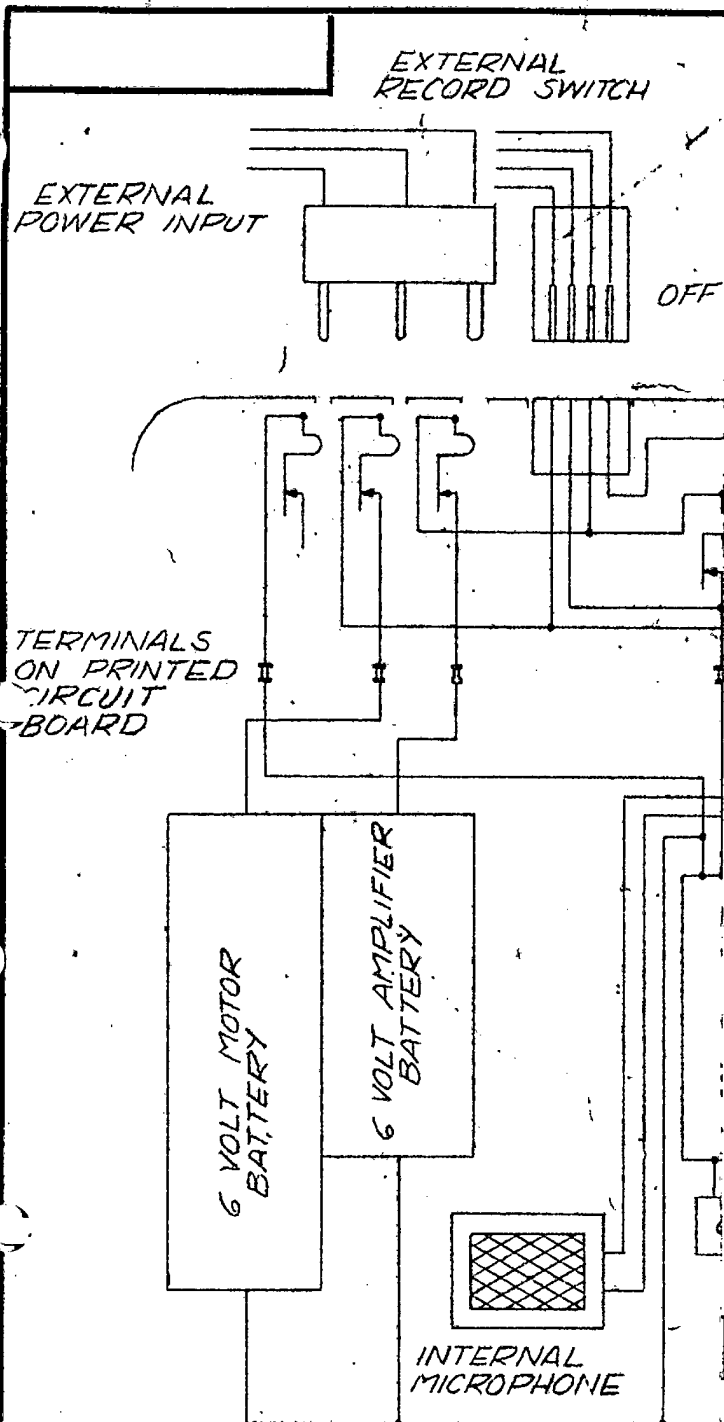
$f$  = frequency in cps.

$K$  = Correction factor for slippage (0.024)

therefore: Motor speed =  $f/2$

$$S_t = Kf = 0.024f$$

$$f = S_t / 0.024 \text{ in/sec.}$$



BM112

RELEASED

NO. REQ.	DESCRIPTION	DWG. NO.
ITEM NO.	FINISH	NO. REQUIRED
MATERIAL	HEAT TREAT	HARDNESS

WIRING DIAGRAM OF CONTROLS

E	SHEET NO.	OF	SHEETS
BY E.F.P.	DATE 3-10-58	DWG. NO.	
CHECKED	DATE	BM112	Fig A
	DATE		

DESIGN VARIATIONSMAGNETIC HEAD

(#4, #5 & #6 spoiled in machining.)  
 (#7 had a lead pulled out too close to replace.)  
 #8 #9 & #10

	#1	#2 & 3	#1	#2	#3	#8	#9 & #10
1. Pole piece cross section.	.006 X .040	.006 X .040	.006 X .040	.010 X .040	.010 X .040	.006 X .040	.006 X .040
2. Pole piece material.	Mu-metal	Carpenter 49	Mu-metal	Mu-metal	Supermaloy	Mu-metal	Supermaloy
3. Pole piece retaining material.	Brass .250 dia.	Brass .250 dia.	Brass .250 dia.	Stain. Steel 303 .312 dia.	Stain. Steel 303 .312 dia.	Stain. Steel 303 .340 dia.	Stain. Steel 303 .340 dia.
4. Wire size and number of turns.	#40 .0035 dia. 60 turns	#40 .0035 dia. 60 turns	#40 .0035 dia. 60 turns	#40 .0035 dia. 60 turns	#43 .0025 dia. 120 turns	#43 .0025 dia. 120 turns	#43 .0025 dia. 120 turns #43 .0025 dia - 60 turns
5. Air gap material and amount.	Gold Leaf	Gold Leaf	Gold Leaf 0.000003	Gold Leaf 0.000003	Alum. Dep. .000010	Alum. Dep. .000030	Alum. Dep. .000030
6. Method of retaining pole pieces.	Cement	Cement	Cement	Pressed & Spun	Pressed & Spun	Cement	Cement
7. Method of securing pole piece retainer.	Dowels & Screws	Dowel & Screws	Dowel & Screws	Pressed Rings & Dowels	Pressed Rings & Dowels	Pressed Rings & Dowels	Pressed Rings & Dowels
8. Lapping of flat surface.	Convex method	Convex method	Hand Lapped	Lapped to 3 rms. rms. 0.000004	Lapped to 3 rms. flat to 0.000004	Lapped to 3 rms. flat to 0.000004	Lapped to 3 rms. flat to 0.000004
9. Lapping of O. D.	-----	-----	Hand Lapped	Grd. & Hand Lapped	Diamond Centerless Grd.	Diamond Lapped between ctrs. .100 off center	Diamond Lapped between ctrs. .100 off center
10. Adj. Features.	None	Adj. Mtg.	Adj. Mtg.	Adj. Mtg.	Adj. Mtg.	Adj. Mtg.	Adj. Mtg.

FIGURE 1

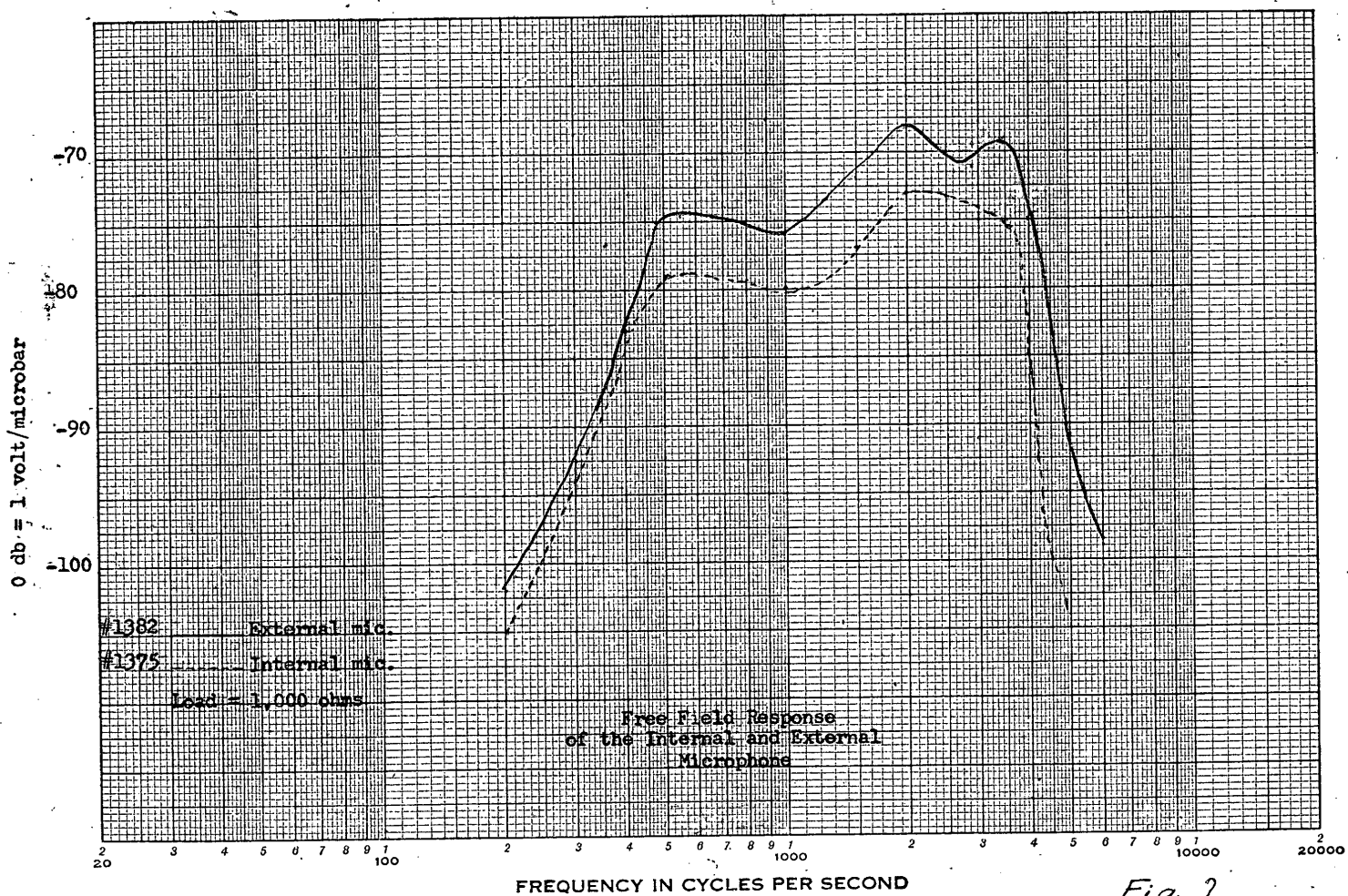
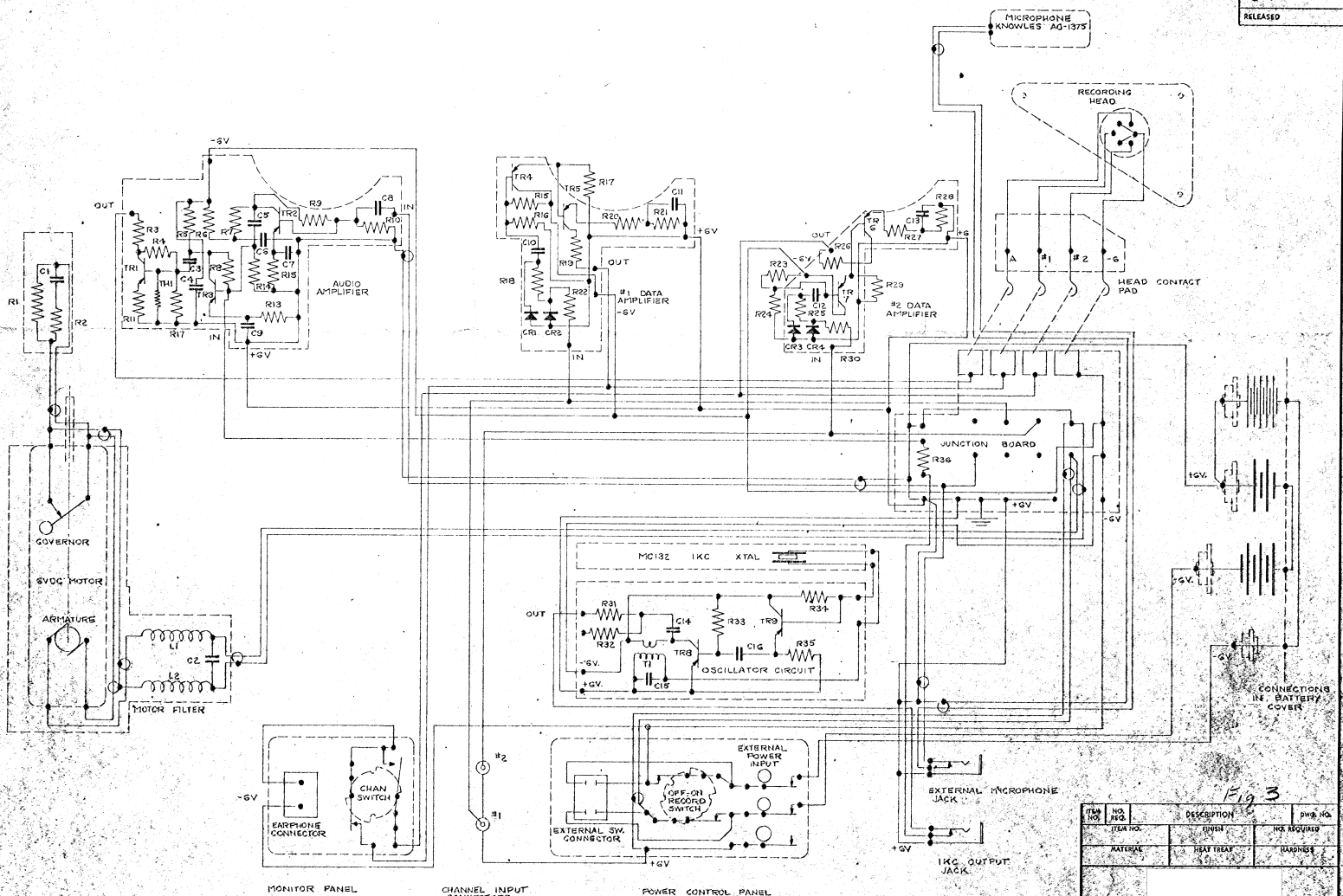


Fig. 2

CMIIZ-  
RELEASED



**Fig 3**

ITEM NO.	NO.	DESCRIPTION	QTY.	REMARKS
1	1	MATERIAL	1	REMARKS
2	1	HEAT TREAT	1	REMARKS
3	1	BARBERS	1	REMARKS

**RECORDING WIRING DIAGRAM**

SCALE: 1" = 1" SHEETS: 1 OF 1

DATE: 10-1-58

CHECKED: [Signature] DATE: 10-1-58

APPROVED: [Signature] DATE: 10-1-58



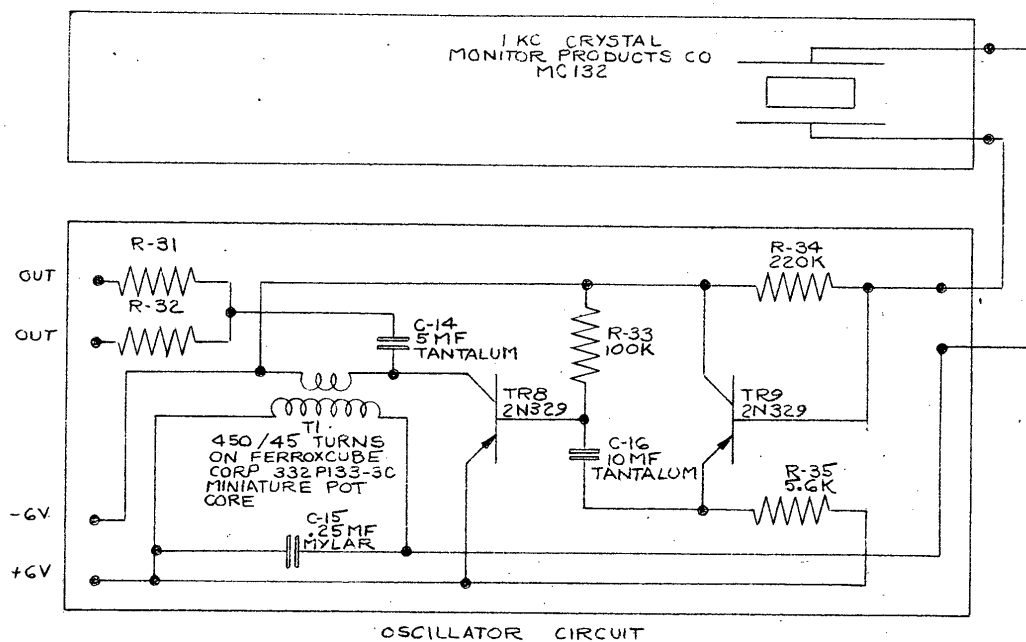


Fig. 4

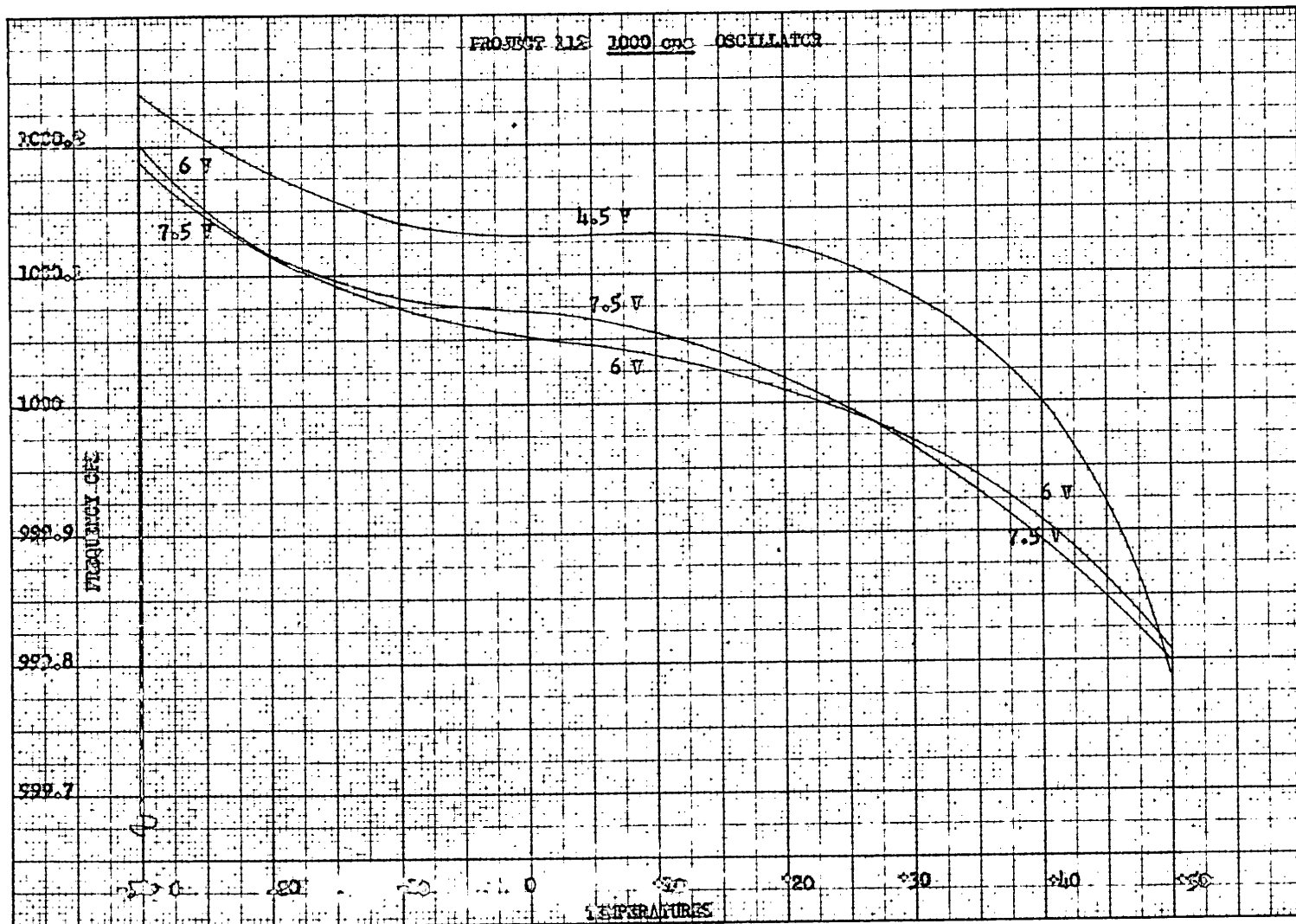


FIGURE 5

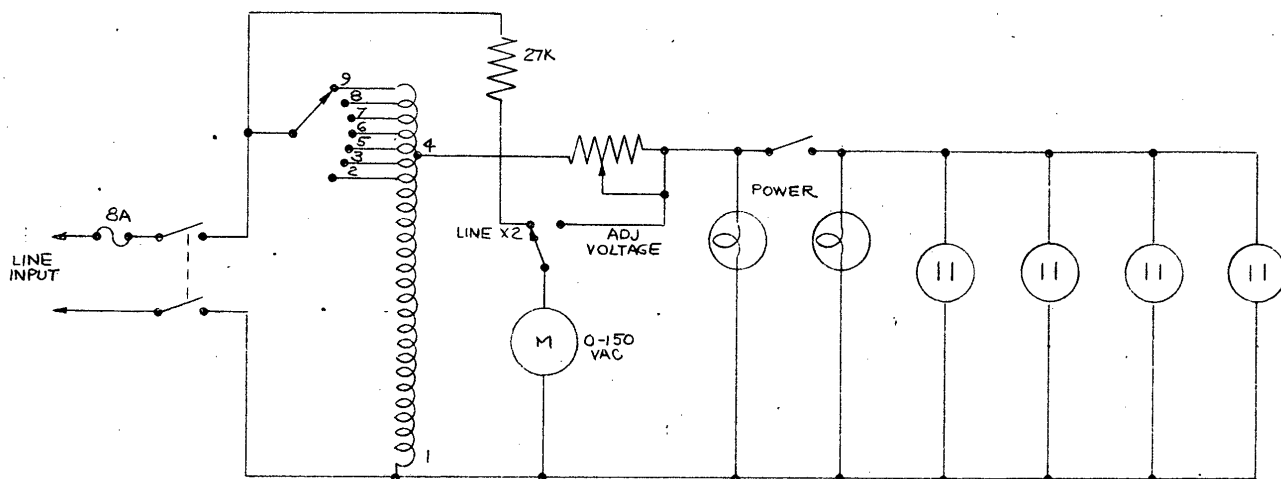


Fig 6

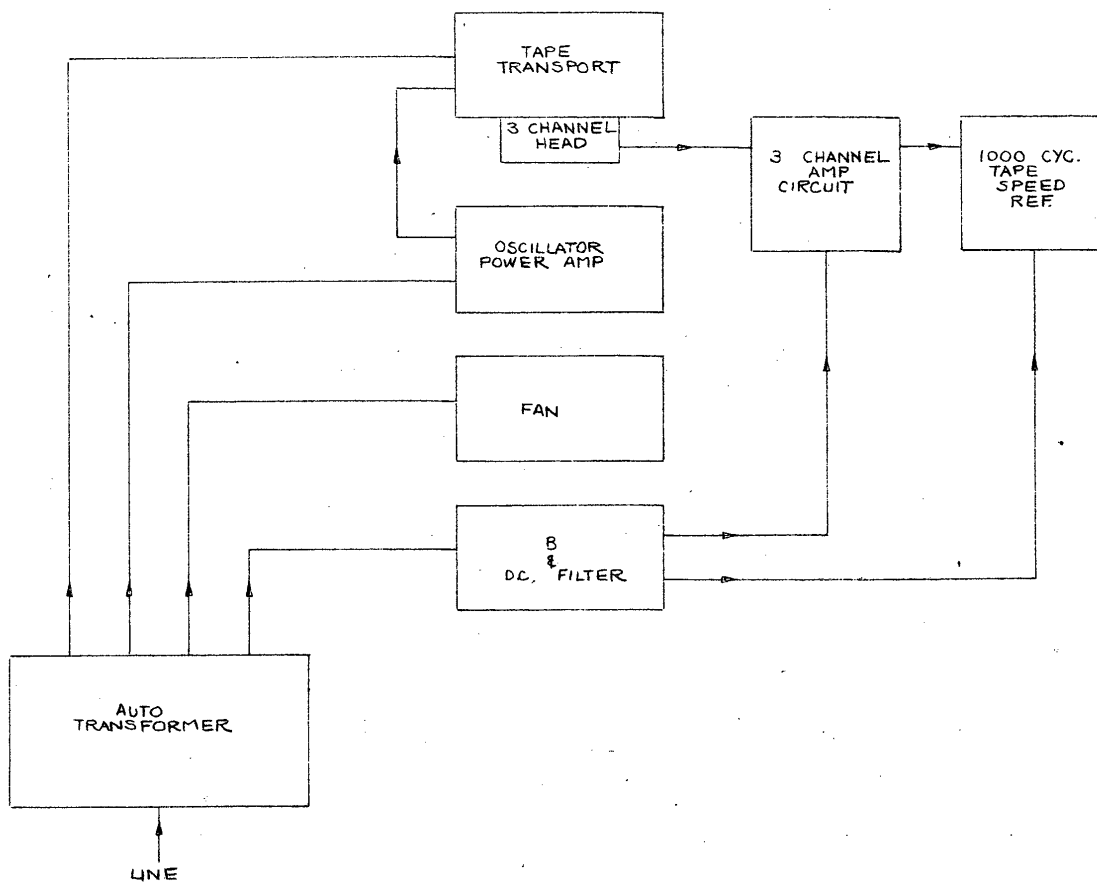
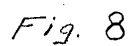
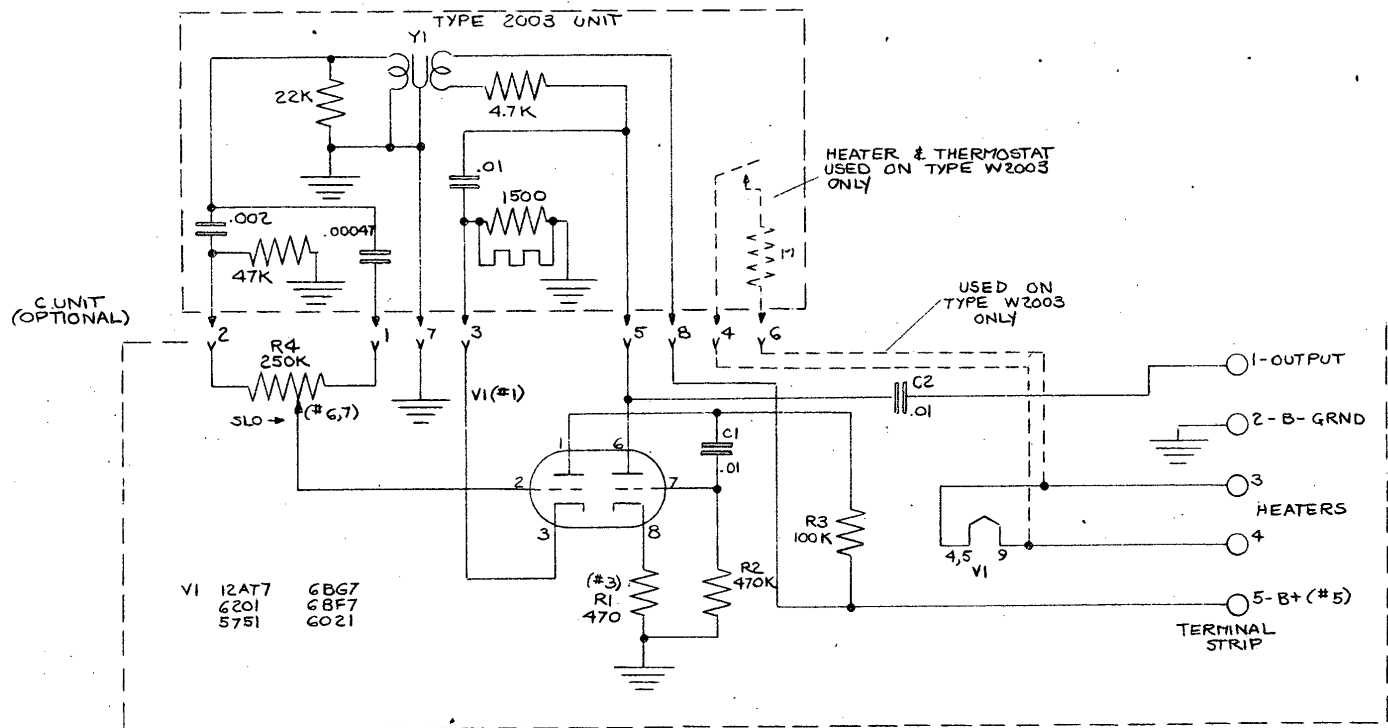


Fig. 7

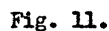






1 KC Tuning Fork Oscillator

Fig. 10.





**K&E** AUDIO FREQUENCY METER  
KEUFFEL & ESSER CO. MADE IN U.S.A.

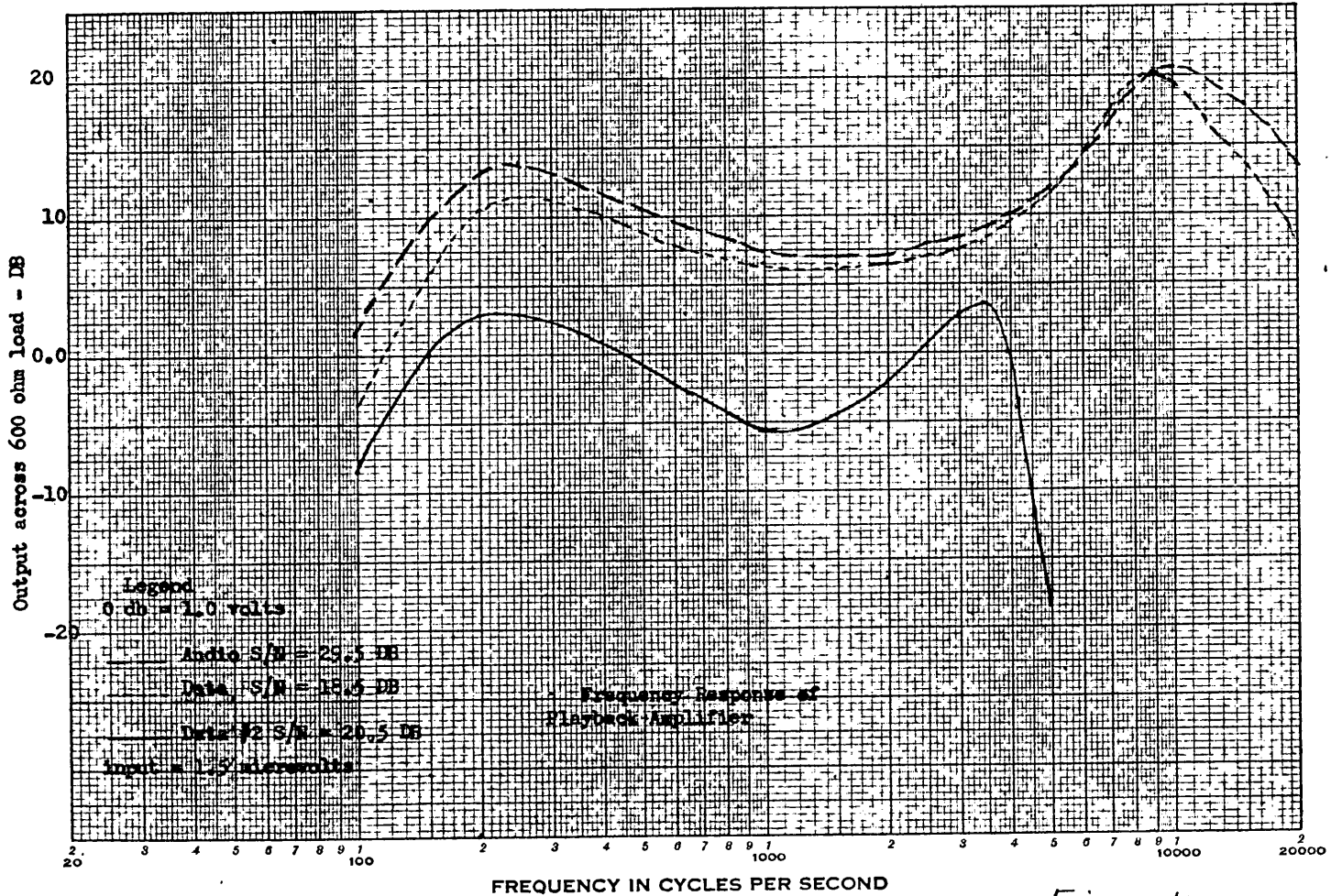
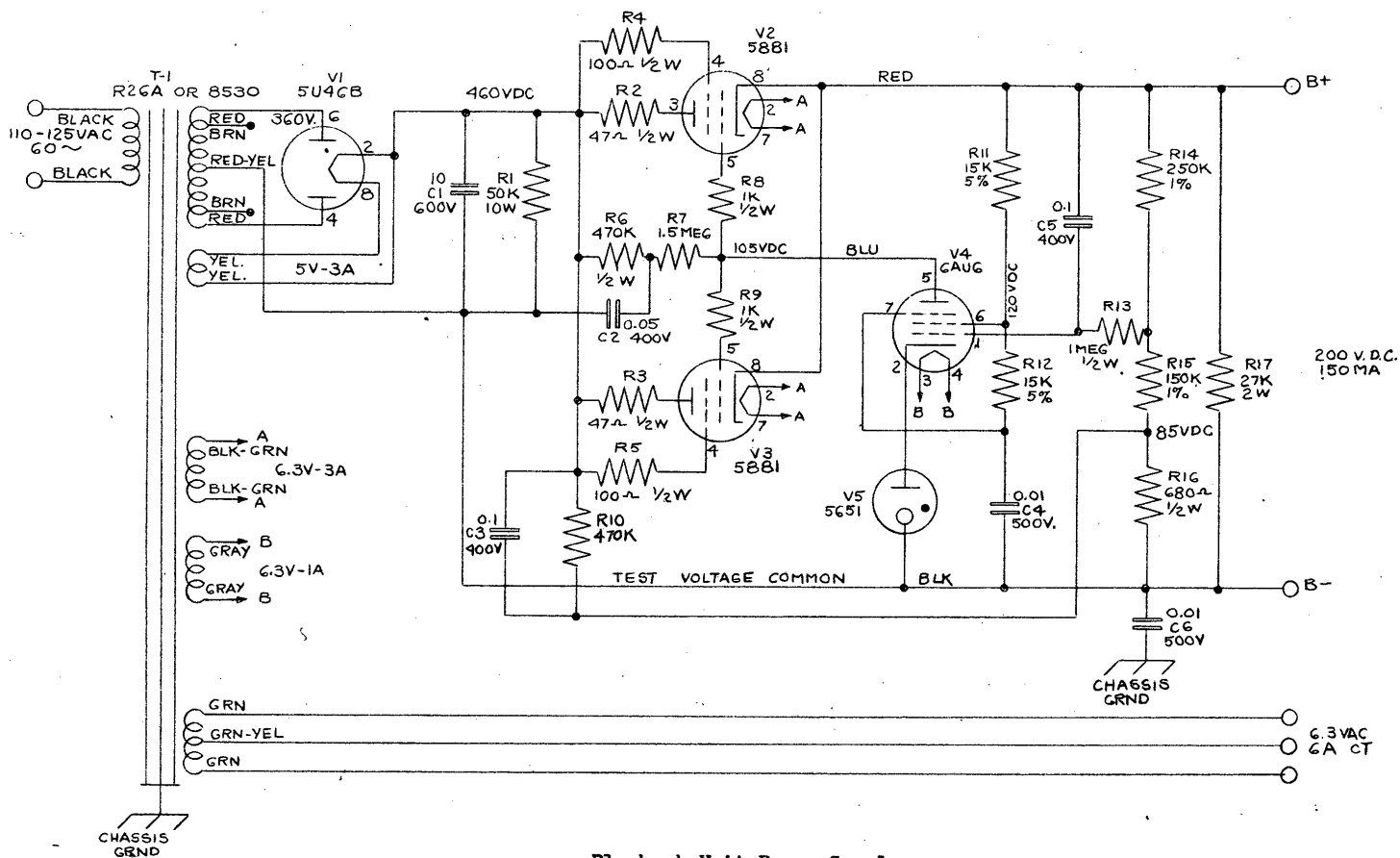


Fig. 12



Playback Unit Power Supply

Fig. 13

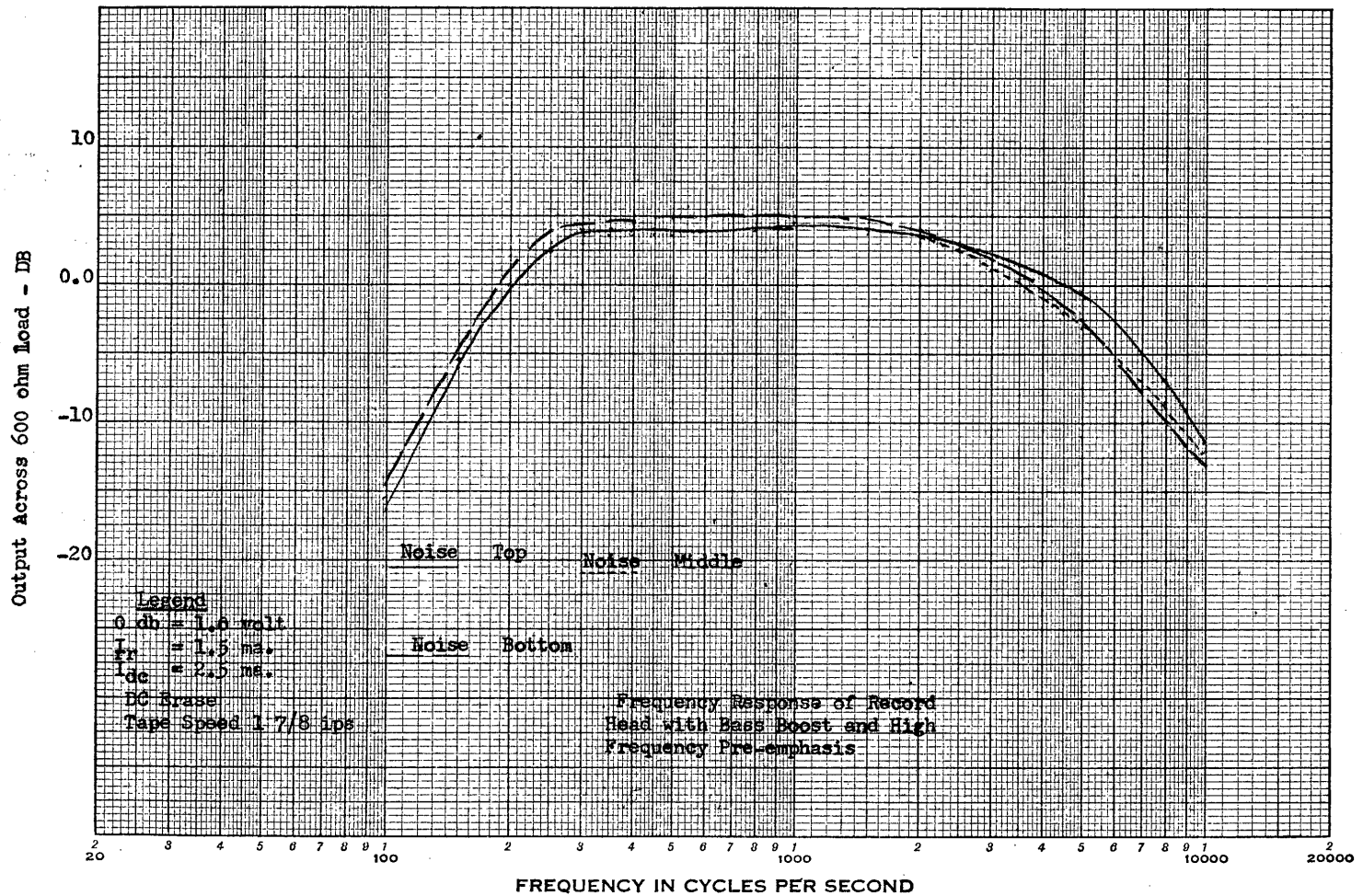


Fig. 14

K&E KEUFFEL & ESSER CO. MADE IN U.S.A.

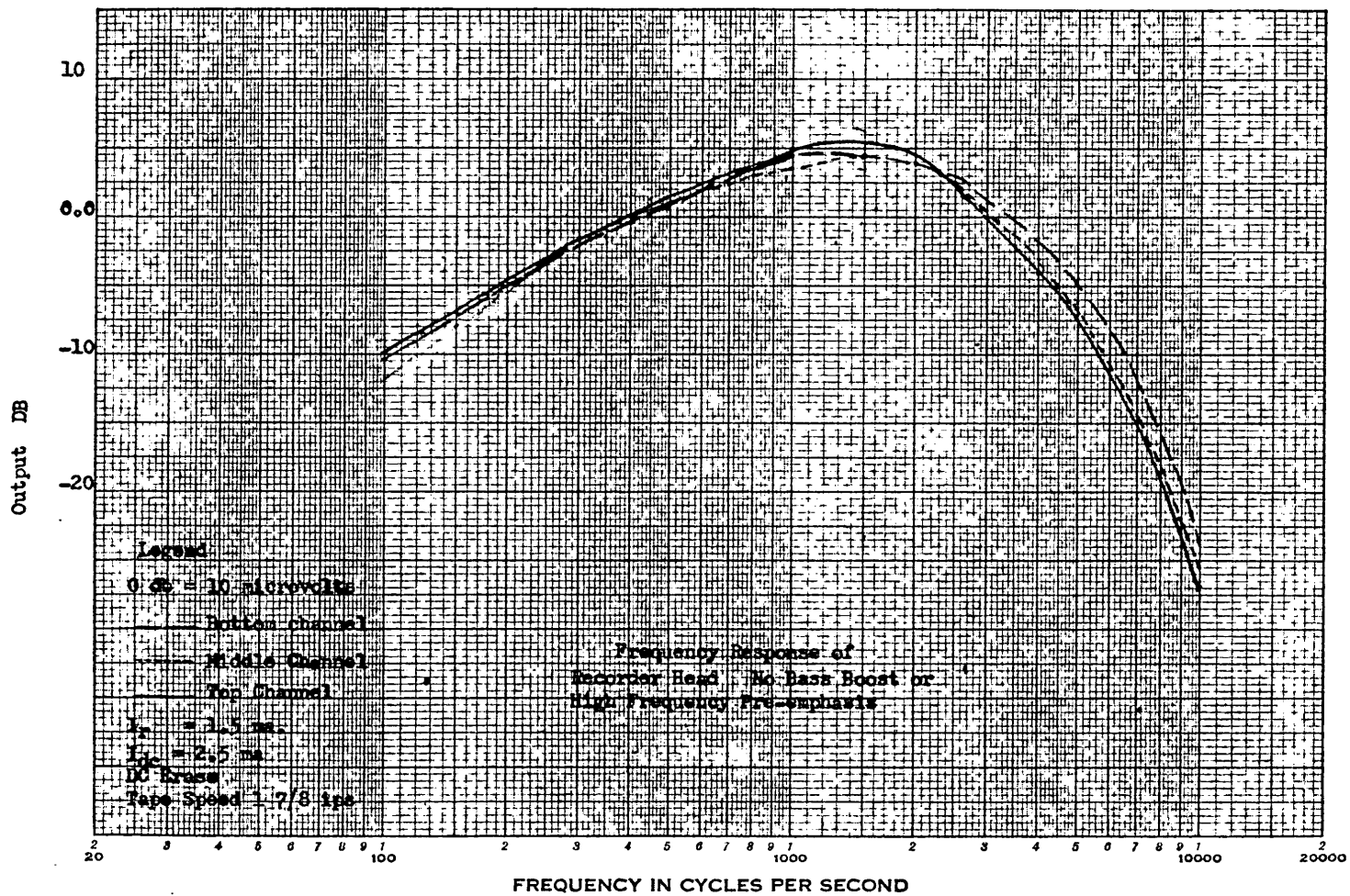


Fig. 15

K&Z KEUFFEL & ESSER CO. MADE IN U.S.A.

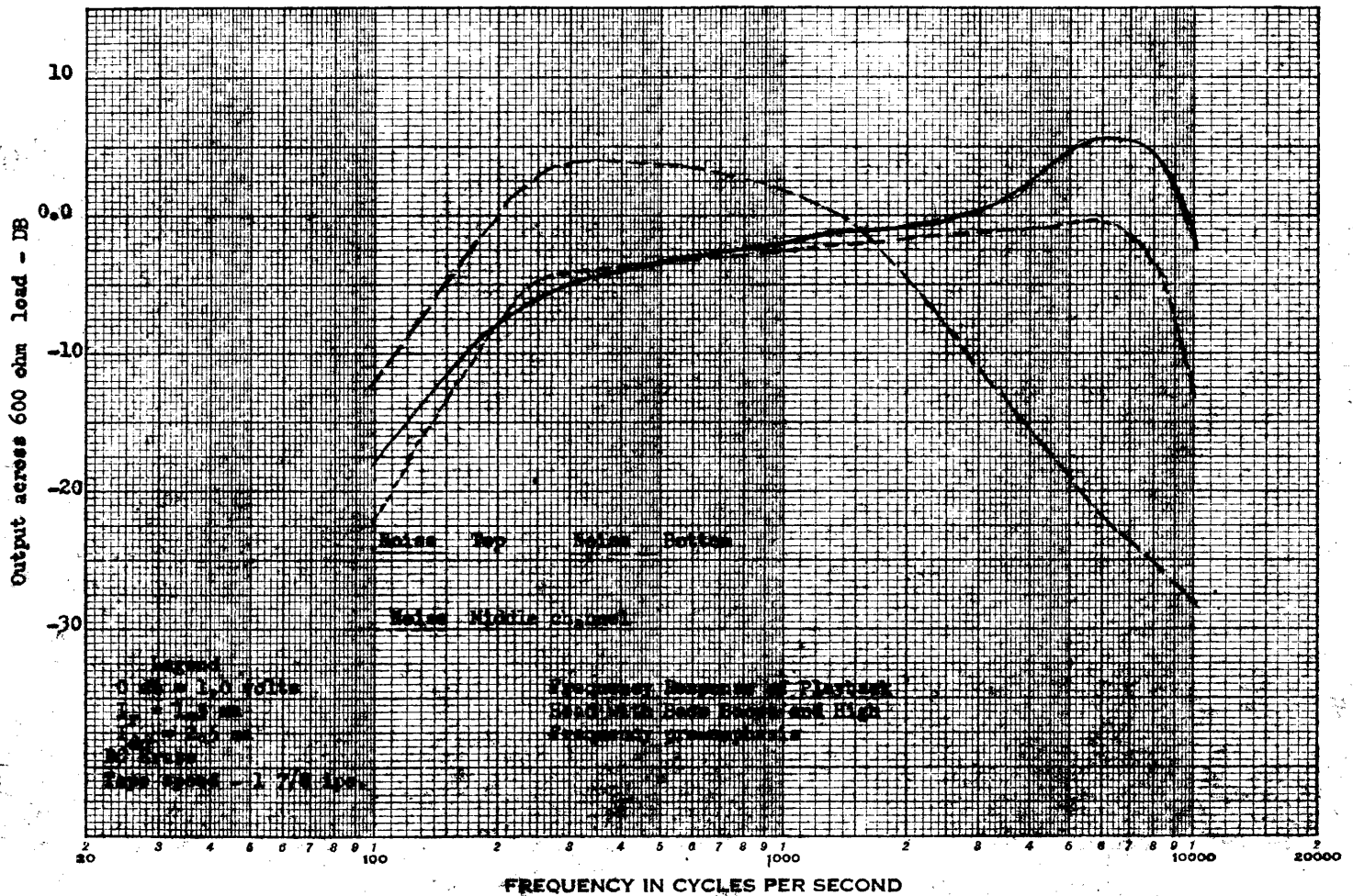


Fig. 16

K&E AUDIO FREQUENCY 333-400  
KEUFFEL & ESSER CO. MADE IN U.S.A.

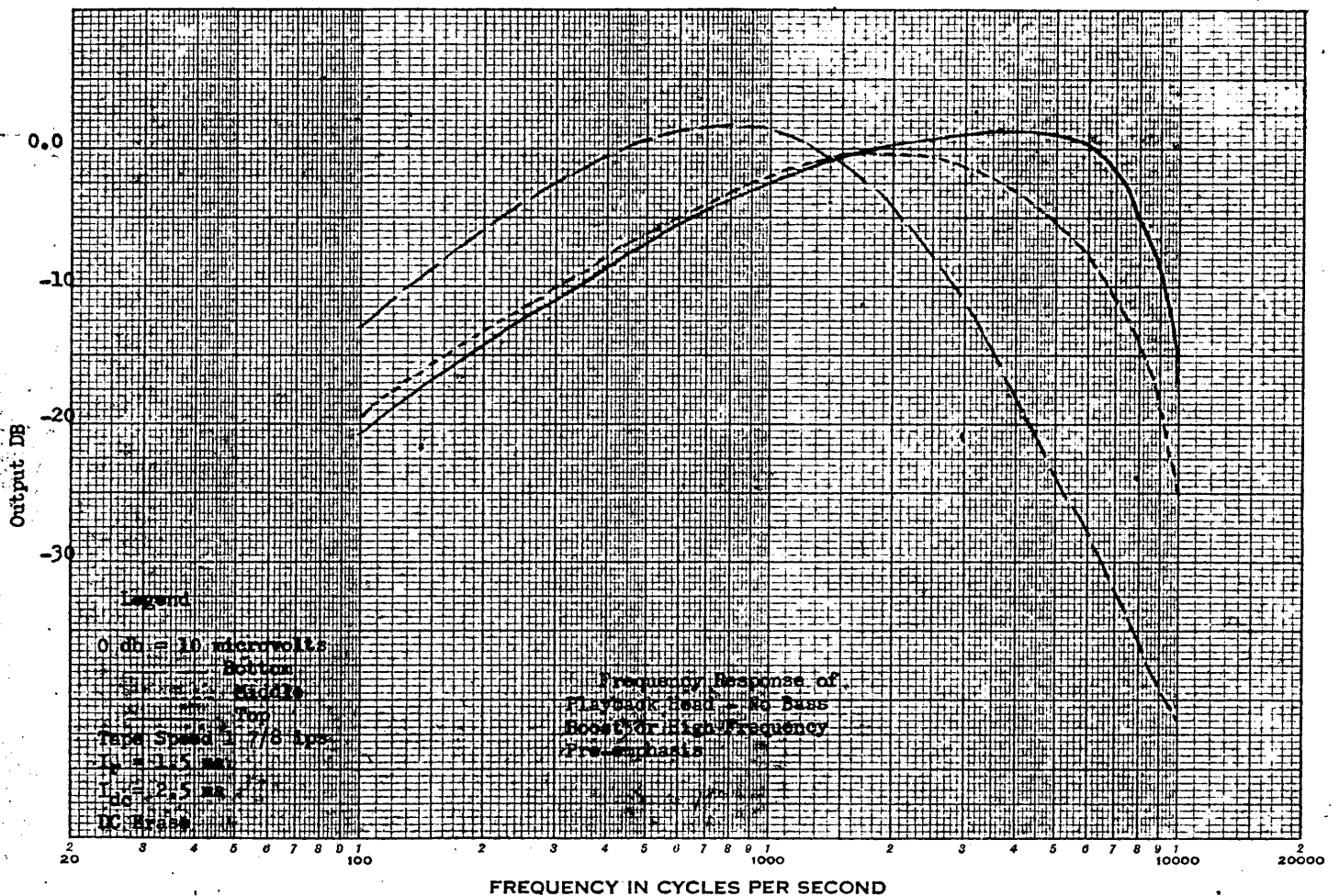


Fig. 17



K<sup>2</sup> KEUFFEL & ESSER CO. MADE IN U.S.A.

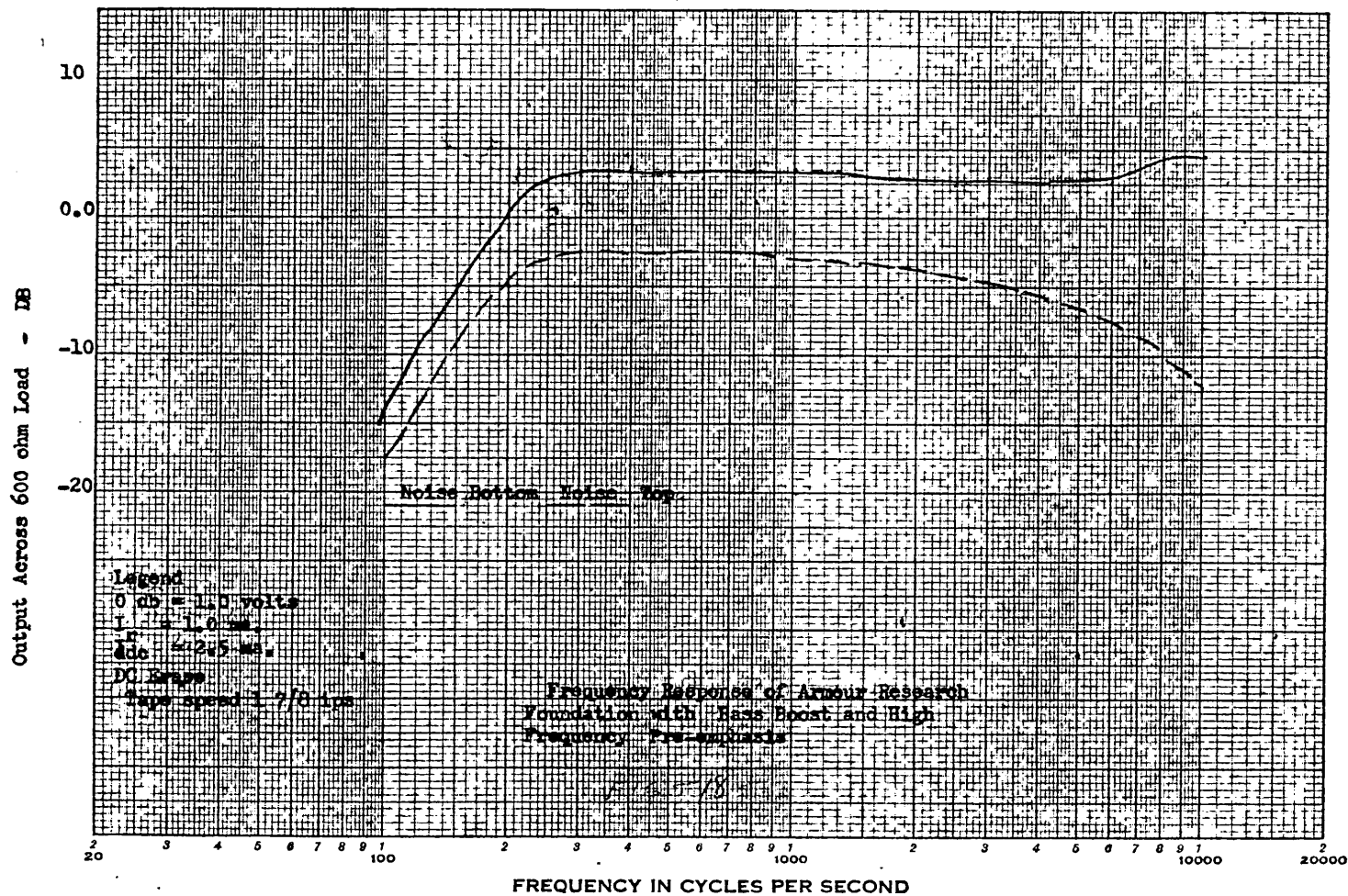


Fig. 18

**K&E** AUDIO FREQUENCY 359-466  
KEUFFEL & ESSER CO. MADE IN U.S.A.

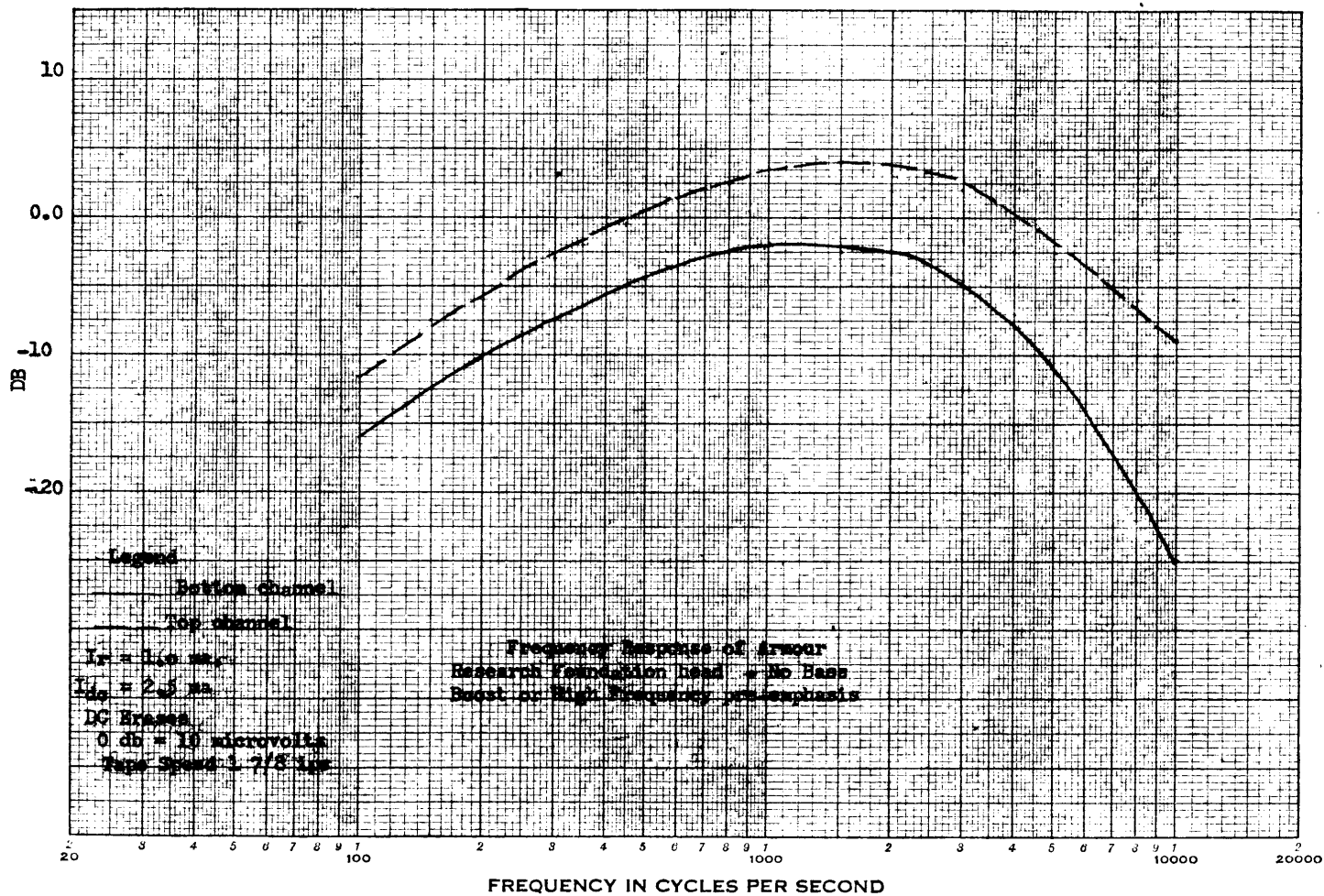
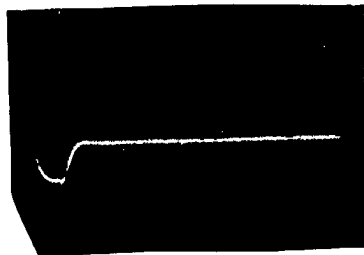


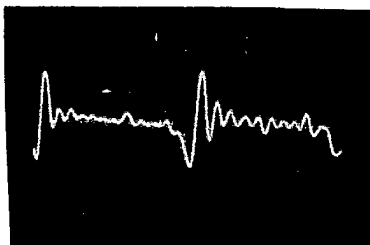
Figure 19



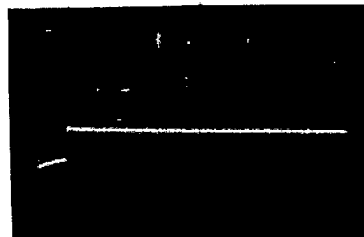
5 usec. pulse  
repetition rate 1,000



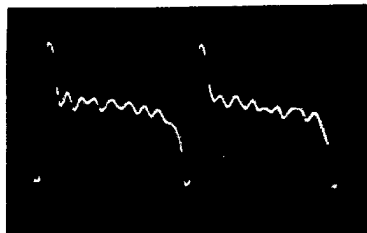
head current 1.86 ma/cm  
time base 5 usec./cm



single sweep 5v/cm time base 200 usec./cm multiple sweep  
50 usec. pulse  
repetition rate - 1,000



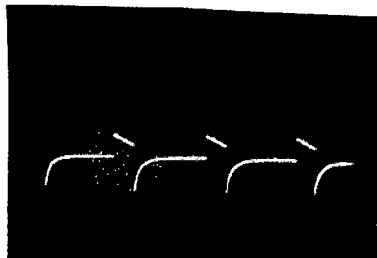
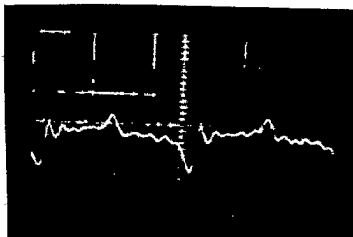
head current 1.86 ma/cm  
t.b. 50 usec/cm



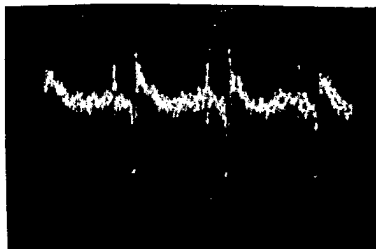
single sweep 5v/cm t.b. 200 usec/cm multiple sweep  
500usec. pulse repetition rate - 1,000



head current .83ma/cm single sweep 5v/cm time base usec. 5v/cm  
5,000 usec. pulse repetition rate - 1,000 t.b. 200 usec/cm



head current 0.83 ma/cm  
t.b. 2msec/cm



single sweep 5v/cm time base 2msec/cm multiple sweep

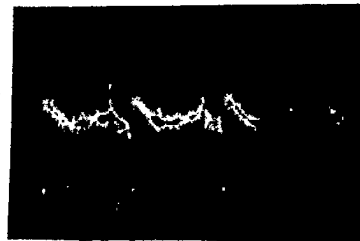


Fig. 20

## A p p e n d i x

### REPAIRED    PLAYBACK    UNIT

#### 1. POWER OSCILLATOR

- 1.1 The playback is a self contained unit in a single cabinet. It operates from a voltage source of 40 to 65 cps with input voltages of 70, 94, 120, 150, 190, 230 and 270 volts. The voltage can be adjusted by means of a multi-position switch in conjunction with a rheostat and panel meter. A range switch is provided with the meter to read directly or X2. Figure 1A is the circuit diagram. Figure 2A is a block diagram of the Playback Unit.
- 1.2 Since the source frequency may vary from 40 to 65 cps, the capstan on the transport mechanism is driven from a 2-phase motor with a separate frequency controlled power source. A Model FCR-100 Sorensen power oscillator, with slight modification, drives the capstan motor. The oscillator can be varied over a wide range of frequencies resulting in a continuously variable tape speed control. The tape speed can be manually adjusted from the control panel over a range from 1.0 ips to 3.5 ips. Since a 2-phase motor is used, a reasonably correct value of capacitance is needed. The approximate capacitance is automatically supplied by the tape speed dial, when it is rotated, by means of a cam switch. The capstan motor will operate from 45 to 150 cps without any adjustments. The power oscillator produces an excellent wave form with practically no harmonics nor can any frequency drift be detected. Figure 3A is the circuit diagram of the modified model FCR-100 Sorensen power oscillator.
- 1.2.1 Due to the excessive heat and A. C. hum, the power oscillator had to be located in a well ventilated area and physically removed as far as possible from the tape head and amplifier inputs.

#### 1.3 Tape Transport

With the exception of the following parts, the tape transport is the same as the unit originally shipped.

Replaced: The capstan assembly and pinch roller  
The tape head holder  
The front panel

- 1.3.1 The capstan assembly, which is that used for the Ampex Model 350, gives a little better figure for wow and flutter than the original playback unit. All switches are identified as to their functional operation along with a few instruction notes.

1. 3. 2 As with all tape recorders, fast moving tape should never be dragged across the head. Incorporated in the tape transport circuit is a safety switch which breaks the power to either the supply or take-up motor if the tape head cover is not raised, which in turn, lifts the tape from the head.
1. 3. 2A To the left of the supply reel is a head alignment tool mounted in a spring clip. The tool has an Allen wrench for the set screw and a Hex wrench concentric to a screw driver tip.
1. 3. 3 The wow and flutter was measured with a Furst Electronics 3 KC model 115-R wow and flutter meter and found to read peak. An RCA, 3 KC 0.1% rms recorded tape was used to check the wow.
1. 3. 4 The capstan should occasionally be cleaned with alcohol and wiped dry. The capstan bearings need very little oiling and the capstan shaft should at all times be kept "bone" dry. Figure 4A is the circuit diagram of the tape transport.
1. 4 Tape Speed Indicator

During playback, the tape speed can be adjusted to correspond to the recorded tape speed. This is accomplished by comparing the 1 KC reference signal recorded on the tape with a 1 KC reference signal built into the playback unit system. Two indicators are employed for determining the proper tape speed. First, a meter is used in conjunction with a frequency sensitive circuit to indicate whether or not the recorded 1 KC signal being played back is high or low, thereby indicating that the speed is either fast or slow. The tape speed can then be annually adjusted to correct the difference indicated.

The second indicator is used when the meter indicator shows that the tape speed is nearly correct. A neon bulb indicator flashes the difference beat of the two frequencies. As the tape speed is finally adjusted, the beat frequency is reduced to zero. However, due to the wow and flutter introduced during recording and playback, the neon indicator never actually reaches a null state. The rate of flashes due to the wow and flutter are low in frequency and occur more or less randomly. More rapid repetitive flashes result from the tape speed being slightly fast or slow, giving a definite periodic beat frequency between the two reference signals. Figure 5A is the circuit diagram of the speed indicator just described with some modification of the original. Figure 6A is the circuit diagram of the 1 KC tuning fork reference oscillator used in the playback unit.

### 1.5 Playback Amplifier

The head winding of each track is connected to an amplifier. The two data amplifiers are identical. Equalization is employed to obtain an output frequency response of the overall record playback system of  $\pm 3$  db from 250 cps to 10 KC. The third amplifier has equalization for voice and has a cut off at 4 KC. Figure 11 is the circuit diagram of the three amplifiers and auxiliary output. An input transformer is used with each amplifier to attain an input level suitable for vacuum tube amplifier operation. Equalization is applied in a feedback circuit between the third and fifth stages of each amplifier. The audio amplifier (channel #1) contains a 1 KC reject filter which is in use at all times except when it is desired to listen to the 1 KC recorded signal on the tape.

- 1.5.1 The input impedance of the playback amplifiers is approximately 10 ohms, and will not overload at 50 microvolts input or less. At full gain setting, the last stage of the amplifier will distort if the input signal exceeds three microvolts. The gain control is in the grid of the last stage. When not in use, the amplifiers are terminated into a 600 ohm load that is removed when a phone plug is inserted into the jack.
- 1.5.2 The output can be received at the head phone plug and along with the volume output meter, can be read or heard. A phone jack on top of the audio chassis is used to make connection to the speed indicator to obtain the recorded 1 KC. The back of the chassis contains polarized connectors for the tape head and power inputs.

### 1.6 High Voltage D. C. Supply

A Dressen-Barns regulated power supply is the D. C. source for the amplifier. Figure 13 is the circuit diagram for the power supply. To minimize amplifier noise, D. C. voltage is used on the first two tubes filaments of each amplifier. Figure 9A shows the circuit employing a full wave selenium rectifier type battery charger with a pi filter.

## 2. OPERATING INSTRUCTIONS

Viewing the cabinet from the front and starting from the top are five separate chassis and a blank panel.

- 2.1 The tape transport.
- 2.2 The three-channel high gain amplifier with a 1 KC reject filter in channel #1. The three channels can be received simultaneously in the mixer output.

- 2.3 The tape speed indicator.
- 2.4 The blank panel is used for a heat sink and magnetically shields the amplifier from the power oscillator.
- 2.5 The power oscillator to drive the variable speed motor.
- 2.6 The auto-transformer with voltage adjustments.
- 2.7 Figure 3 shows a block diagram which also includes the B + voltage and D. C. filament supply for the amplifier. This chassis is located behind the tape deck inside the cabinet.
- 2.8 A stepped transformer is employed so that the system can be operated from a variety of A. C. power sources. Since the frequency may vary from 40 to 65 cycles per second (cps), the capstan on the transport mechanism is driven from a separate frequency controlled power source. The frequency of the Sorensen oscillator power amplifier can be varied over a wide range of frequencies, resulting in a continuously variable tape speed control. The tape speed can be manually adjusted from the control panel over a range of from 1 to 3-1/2 ips. Several components of the playback system are modified commercial units.

### 3. OPERATING PROCEDURE

- 3.1 Close power switch on bottom panel and adjust voltage with both the coarse and fine knob to read 115V. A. C. on the panel meter.
- 3.2 Turn equipment switch on.
- 3.3 Turn power switch of the power oscillator on.
- 3.4 Flip the capstan motor switch on, located in the upper left hand corner of the tape transport.
- 3.5 The red neon should glow brightly, if not, press 'start - run' switch to start momentarily, and release.
- 3.6 Raise tape head cover.
- 3.7 Place tape to be played on the left hand spindle of the transport and thread tape as indicated by the arrows. Tape must be placed on the two glass rods attached to the cover.
- 3.8 Close cover and press run button. Output can be obtained from any channel regardless of switch setting. (The rotary switch is for head phones and meter).

- 3.9 The 1 KC reject is to keep the 1 KC on the tape out of the head phones on channel #1.
- 3.10 The tape cannot be rewound for fast forward when the tape cover is closed. Cover must be raised for fast tape speeds.

#### 4. CALIBRATION OF TAPE SPEED INDICATOR

- 4.1 With the tape at a standstill, adjust sensitivity control to one-half rotation.
- 4.2 Null the comparator meter by adjusting the D. C. balance control. This does not need frequent adjust, i. e. keep between parallel lines in center of meter.
- 4.3 Press the red button on the speed control panel, and null the comparator meter by adjusting the 1000 cps balance control. Then release the button.
- 4.4 Depress the run button on the switch of the transport unit to engage the capstan.
- 4.5 Switch the 1 KC reject filter to "OFF".
- 4.6 Use earphone, connected to the audio (channel #1) output, and listen for the 1000 cps tone.
  - 4.6.1 Adjust tape speed control to null.
- 4.7 Again adjust speed controls so that both halves of the neon indicator glow with the same intensity, or with a minimum beat.
- 4.8 The tape speed dial is continuously variable, the upper scale on the dial reading in approximately inches per second and the lower scale in frequency of the driver oscillator.
- 4.9 Due to the wow and flutter introduced by the recorder and playback unit, the neon light will never be completely extinguished. The faster the beats, the greater the wow and flutter. No further adjustment of speed is necessary unless the recorder speed changes. In that event, the change will be indicated by the two playback speed indicators (meter and neon bulb).

#### 5. ADDITIONAL INFORMATION

- 5.1 A 600 ohm load is always connected to the output jacks, but is removed when a phone plug is inserted.
- 5.2 The VU meter will not handle the maximum output of the amplifier, therefore, although this meter may be off scale, it does not necessarily mean that the output signal is distorted.

- 5.3 The playback head can be aligned by removing the two screws that hold the black cover (as indicated by the arrows) and with the head alignment tool found on a clip to the left of the supply reel, adjust head for maximum output.

CAUTION: The nuts on the two cadmium plated and the two set screws are the only adjustments to be made. DO NOT rotate the cadmium screws, (they hold the head to the base plate). The alignment tool has an internal screw driver to hold the screws, while the nuts are rotated.

- \* \* \* -

THE FOLLOWING TEN PAGES AND PARTIAL  
PAGES ARE REPRODUCED FROM THE  
MAINTENANCE MANUAL FOR THE FCR 100  
VARIABLE FREQUENCY POWER SUPPLY

## II. SPECIFICATIONS

Input Voltage Range	105 - 125 VAC
Input Frequency	45 - 65 cycles
Output Voltage	115 VAC nominal
Adjustment	0 - 130 (Voltages under 75 volts have high distortion and modulation.)
*Output Voltage Regulation	$\pm 1\%$ for load $\pm 1\%$ for line
Output Frequency Range 1	45 - 300
Range 2	300 - 2000
Dial Calibration Accuracy	$\pm 2\%$
Output Frequency Regulation	$\pm 1\%$ against all variations $\pm .01\%$ may be obtained by using an external frequency standard
Frequency Drift	less than 1% over 24 hour period
Load Range	0 - 100 VA at 105 - 125 Volts output. Load derated at reduced output voltage with minimum load impedance of 110 Ohms.
Power Factor	Unity to 0.7 lagging at 100 VA Unity to 0.5 lagging at 50 VA Fully inductive at 25 VA
Output Distortion	Max. 1% for 75V - 125V Output
**Output Modulation	Nom. 1% for 75V - 125V Output



Ambient Temperature Range 0 to 40°C. (32 to 104.0°F).

Tube Complement

5R4GY (2), 6X4, (1) OD3/VR-150 (2)  
6BL7GT (1), 811A (2), 12AU7 (2) 12AT7 (1),  
6F6GT (1), 6J7 (1)

Net Weight

75 Lbs.

#### \* Voltage Regulation

The term, voltage regulation, of this unit assumes an oscillator input of fixed amplitude. This is a master oscillator power amplifier unit with no closed loop circuit. Therefore, the output voltage stability is only as good as the Wein bridge oscillator. This oscillator is subject to drift due to shock, temperature, and aging effects and also has a frequency response of 1 db or less. The regulation referred to in the specification assumes a fixed oscillator voltage. The oscillator voltage specs. are as follows:

- ± 1 db vs. frequency
- ± 2% vs. mechanical shock
- ± 3% vs. temp. (0-35°C.)

\*\* This figure assumes no input voltage modulation. If input voltage modulation is present, the output modulation will be directly affected by it.

### III. INSTALLATION AND OPERATION

#### A. Terminals, controls

##### 1. Input Connection

The input power is applied by means of a line cord utilizing a three prong plug. Since the third prong of this plug is connected to the FCR 100 chassis, connection of the line cord to the appropriate receptacle automatically grounds the equipment. If the user does not have three prong outlets available, he should use an adapter. The user should make sure that the extra wire (coded green) coming out from the adapter is solidly grounded to the power line wiring system (preferably soldered).

##### 2. Stand-By Power

Power is obtained by turning to "On" the toggle switch, SW-1, at the left side of the instrument panel.

CAUTION: THE INPUT SWITCH, SW-1, DISCONNECTS THE INPUT LINE AFTER THE INPUT FUSE. FOR SAFETY REASONS THE INPUT LINE SHOULD BE DISCONNECTED EXTERNALLY PRIOR TO WORKING ON THE INSTRUMENT.

B. Fuses

1. Fuse F-1 protects the input transformer T-1, and tubes, and is located on the lower left center of the instrument panel.
2. Fuse F-2 protects against output overload, and is located on the lower right center of the instrument panel.

C. Pilot Lights

1. Pilot light 1 (PL1) located on the lower left of the instrument panel indicates filament power to be on.
2. Pilot Light 2 (PL2) located on the lower right of the instrument panel indicates output power to be on.

#### D. Nameplates

☐ strongly suggests that the nameplate be retained even if the instrument is to be incorporated into other equipment. This will eliminate later difficulties if service or parts are required.

STAT

#### E. To Place the Unit in Operation

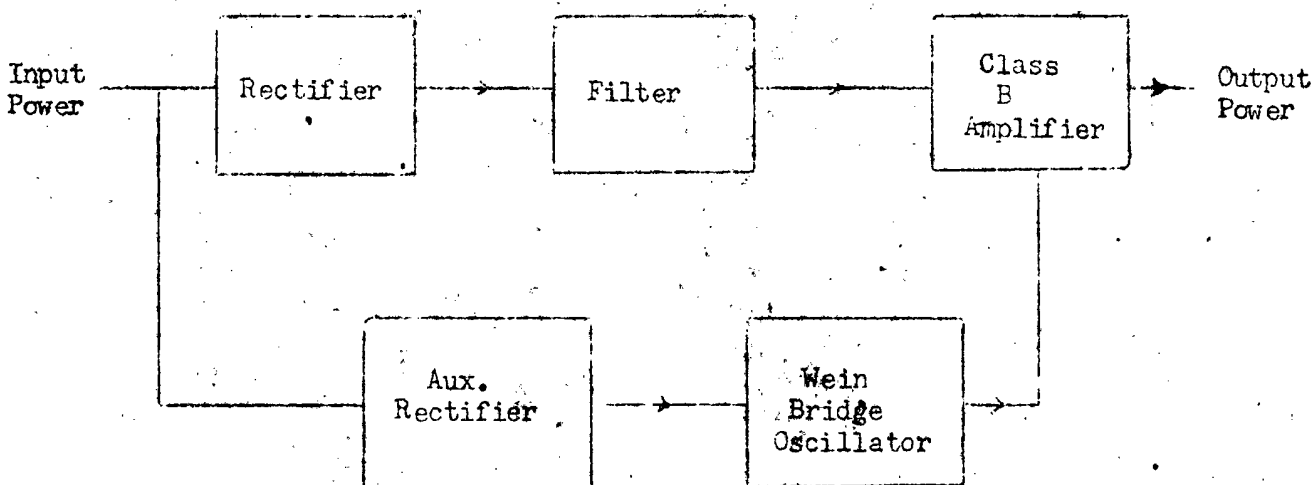
CAUTION: BEFORE OPERATION IS BEGUN, PLEASE REVIEW THE PRECEDING SECTION WITH REGARD TO CONTROLS.

1. Plug the input line cord into a 115V, 60 cycle outlet, as per A-1 above.
2. Turn on the "Stand-By" toggle switch at the lower left side of the instrument's panel. This will cause the pilot lamp PL1 to light and the filament power is now on.
3. Wait approximately 30 seconds to give the tubes a sufficient warm-up period.
4. To apply output power turn the Output Power Switch (SW2), located on the lower right side of the instrument panel, to the "On" position. Pilot light PL2 should now light, and output voltage power should appear across the output terminals.

#### IV. PRINCIPLE OF OPERATION

The operation of this instrument can best be understood by referring to the schematic diagram supplied with each instrument.

- A. The Block Diagram given below will aid in following the circuitry of the various section.



B. The frequency changer may be divided into three main sections with auxiliary equipment. Refer to block diagram on previous page.

1. The main sections and their operations are as follows:

A. Rectifying section consisting of transformer T-1, rectifier tubes V-1 and V-2, filter chokes L-1 and L-2, and filter capacitors C-1 and C-2. This section rectifies the input to provide DC power for the Amplifier section.

B. Amplifier Section consisting of transformer T-2, tubes V-4, V-5, V-11, V-12, and V-13, Audio Input Transformer T-4, and associated resistor and capacitor networks. This section is a class B Audio Amplifier employing a high degree of negative feedback to insure good output waveform and stability.

C. Wein Bridge Oscillator consisting of tubes V-8, V-9, and V-10. The Standard Wein Bridge Oscillator has components selected for two frequency ranges, 45-300 cycles and 300-2000 cycles. A plug and jack arrangement is incorporated for application of an external signal if desired.

D. Listed below are all the components used in this instrument, together with their function. They are presented for your understanding and as a reference source for the functional description of items on the replacement parts list. Reference to the schematic furnished with each instrument will give the position of each component in the circuitry.

C-1, C-2	Filter capacitors main rectifier
C-3	Filter capacitor neg. bias for V-4 and V-5.
C-4	3 section filter capacitor, filters D.C. for oscillator and amplifier sections,
C-5, 6, 7, 8, 9, 10	Part of R-C, Potentiometer and neg. feedback circuit
C-11	Frequency adjust capacitor
C-12, 14	Trimmer capacitors used to align oscillator
C-13	Fixed capacitor used in oscillator alignment
C-15, 17	Coupling capacitors in oscillator
C-18, 23	High frequency filter capacitor in T-4 secondary
C-19, 20, 21, 22	Coupling capacitors in Amplifier
C-24	Capacitor in load compensating circuit used to eliminate high frequency positive feedback
T-1	Input Transformer, filament and DC power
T-2	Output Transformer
T-3	Load compensating transformer
T-4	Audio Input Transformer
L-1, L-2	Filter chokes for main D.C. supply
L-3	Filter choke for oscillator D.C. supply
V-1, V-2	High voltage rectifiers for main D.C. supply
V-3	Rectifier for V-13 D.C. supply
V-4, V-5	Power Output tubes

V-6, V-7	Voltage Regulator tubes to regulate oscillator D.C. supply
V-8, V-9	Oscillator tubes
V-10	Cathode follower for oscillator output
V-11, V-12	Voltage Amplifiers
V-13	Cathode follower driver for V-4, V-5
R-1, R-2	Dropping resistors for voltage regulator tubes
R-3	Dropping resistor for D.C. supply for voltage Amplifier tube.
R-4	Adjustable dropping resistor for negative bias supply
R-5	Discharging resistor for one section of C-4
R-6, R-9	Cathode resistors of V-13
R-7, R-8	Grid resistors of V-13
R-11, 12, 13	Balancing network for plate current of V-4 and V-5
R-10, 11, 12, 13	Resistors in R-C potentiometer network and negative feedback Circuit Amplifier
R-14	Adjustable resistor to provide proper current compensation
R-15	Range centering resistor in oscillator
R-37, 38, 39, 40, 47	Frequency determining resistors in oscillator
R-16	Plate resistor of V-8
R-17, 18	Screen grid divider resistor of V-8
R-19, 20	Negative feedback resistors in oscillator
R-21	Plate resistor of V-9
R-22	Grid resistor of V-9
R-23	Cathode resistor of V-9
R-24, 25	Screen grid divider resistors of V-9
R-26, 46	Output voltage adjustment resistors
R-44	Stabilizing lamp bulb in negative feedback circuit of oscillator
R-27, 28	Grid resistors of V-11
R-29, 31	Plate resistors of V-11
R-30	Cathode resistor of V-11
R-32, 33	Grid resistors of V-12
R-34, 35	Plate resistors of V-12
R-36	Cathode resistor of V-12
SW-1	Input power switch
SW-2	Output power switch
F-1	Input power fuse
F-2	Output power fuse
SW-3	Range switch
PI	Auxiliary frequency input plug
J1	Auxiliary frequency input jack
S1	Selenium rectifier for negative bias supply V-4, and V-5
PL-1	Pilot light input power
PL-2	Pilot light output power

## V. MAINTENANCE AND REPAIR

1. During normal life the unit requires no maintenance or servicing other than the care usually afforded this type of equipment. Tubes should be replaced at the end of their specified life in accordance with the policies established for the particular applications.

2. Spare Parts

All components in the Frequency Changer are of a good commercial grade and can be expected to give a reasonably long period of trouble free service. As the age of the instrument increases, however, some components are likely to deteriorate; we therefore suggest that the customer keep on hand the spare parts as indicated by an asterisk on the Parts List supplied with the unit. In the event it becomes necessary to replace any part, we strongly suggest that the replacement parts be of the same value as the original. Substitute parts should not be used unless we advise that the substitute part will not impair the performance of the instrument.

3. Repair and Trouble Shooting

In the event of malfunctioning of the unit due to deterioration or failure of any of its component parts, a systematic checking procedure will provide the quickest and surest method of locating the difficulty. The following section gives systematic checking procedures which should be followed in locating sources of trouble.

CAUTION: DANGEROUS VOLTAGES EXIST IN THIS INSTRUMENT. PLEASE OBSERVE APPROPRIATE PRECAUTIONS.

The first step in trouble shooting should be to replace tubes. In most cases this is enough to cure the trouble.

- A. If the input power light does not light, check F-1. If it still does not light check the input connection.
- B. If the output switch is turned on and no output voltage appears when the voltage potentiometer is turned up the difficulty is in the oscillator section. Check to see that the oscillator section is providing the proper voltage by placing a V.T.V. across terminals #1 and #5 of oscillator assembly plug. A reading of 10-15 Volts should be obtained for all 5 Volt output.

If no voltage appears across these terminals, check the following:

1. Check Fuse F-2.
2. R-44 located on the chassis under the oscillator assembly may be open or loose. A resistance check of this resistor should read between 350 and 500 ohms with the standard multimeter.

3. Check potentiometer R-19; this potentiometer is factory set for proper negative feedback in the oscillator circuit. If this potentiometer becomes jarred or if the tubes are changed in the oscillator section, the oscillator may fail to provide proper output voltage. Raising the resistance of this potentiometer should provide output voltage.
4. Capacitor C-11 rotor should be isolated from ground, if any part of this circuit becomes grounded, the oscillator circuit will not provide output voltage.

In the event that these checks do not help, the entire oscillator section should be checked.

- C. If the oscillator voltage's are proper and still no output voltage appears check the following:

1. Check the following D.C. Voltages:

- A. From chassis ground to terminal No. 2 of L-1, 1100-1400 V.D.C.
- B. From chassis ground to junction of R-2, L-3, and V-6, 300 V.D.C.
- C. From chassis ground to junction of R-3, and C-4, 350-425 V.D.C.
- D. From chassis ground to plate of V-13, 450 V.D.C.
- E. From chassis ground to C-3, negative 50 V.D.C.
- F. From chassis ground to R-30, 9 V.D.C.
- G. From chassis ground to R-36, 9 V.D.C.

If all the voltages are correct and there is still no output voltage check resistance values and continuity.

- D. If any of the following conditions exist, the internal adjustments are possibly incorrectly set.

1. High distortion
2. Poor frequency calibration
3. Insufficient output voltage
4. Poor load compensation
5. Excessive bounce in output
6. Excessive voltage change with frequency change.

In the event that any of the internal adjustments are incorrectly adjusted, we strongly suggest you contact the factory for further service instructions.

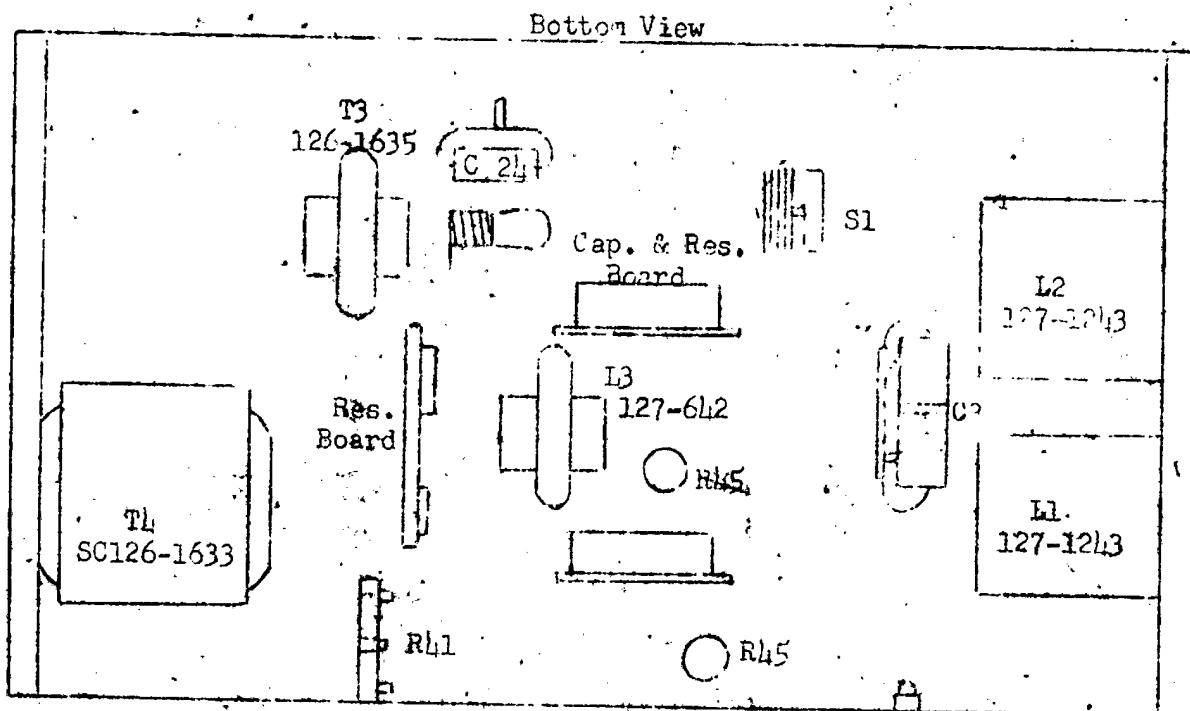
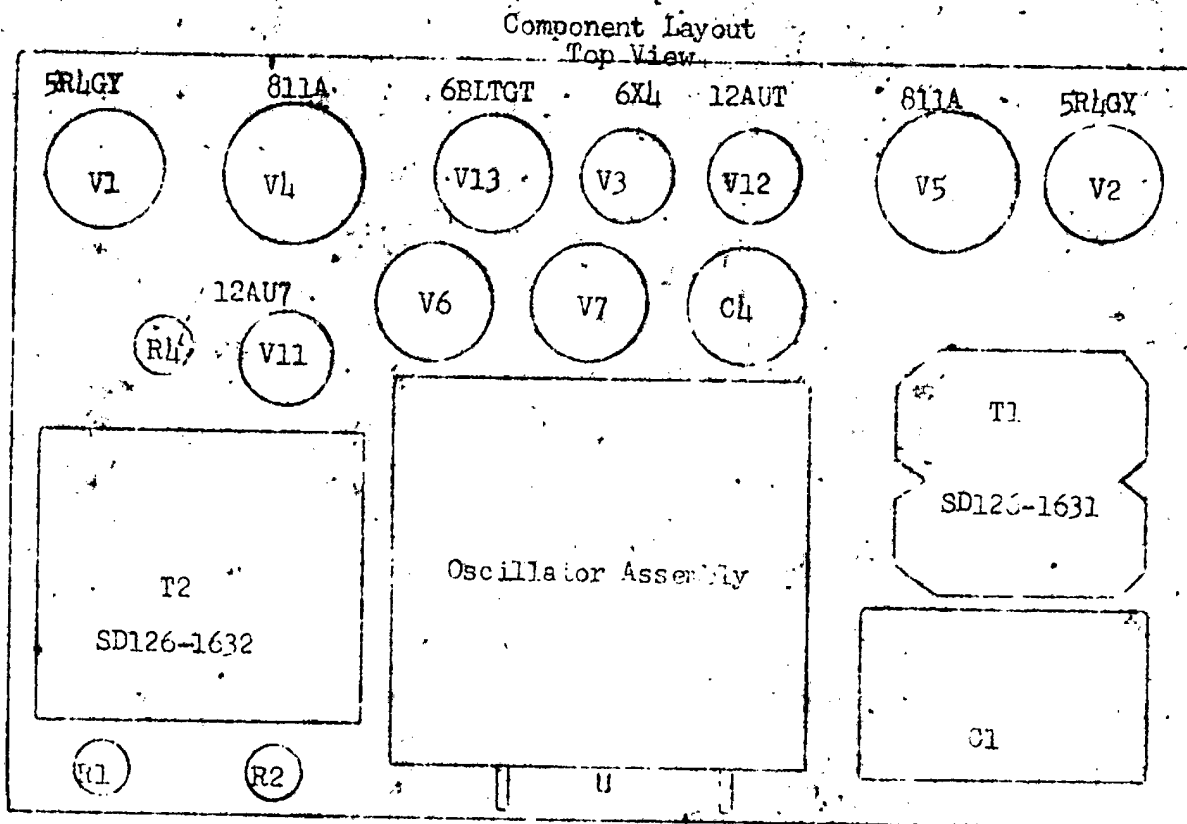
- E. Shown below are a number of waveforms to use as a means of checking the circuitry. The waveforms were taken with a nominal input at both no load and full. The voltages were measured with a standard V.T.V.M.

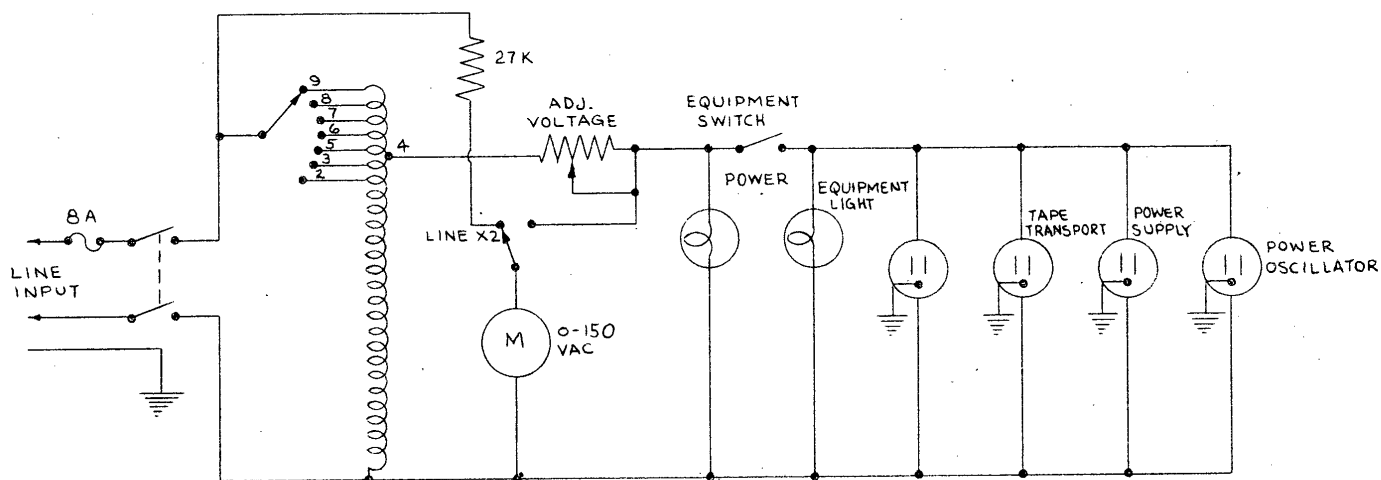
## A.C. Readings Using Ballantine and Scope

VII Pin #7 to B-		VII Pin #2 to B-		VI2 Pin #1 to B-		VI2 Pin #6 to B-		VI3 Pin #3 to B-		VI3 Pin #4 to B-	
N.L.	F.L.	N.L.	F.L.	N.L.	F.L.	N.L.	F.L.	N.L.	F.L.	N.L.	F.L.
.48	1.1	.26	.43	7.8	50	11.0	56	10	36	7.6	47
VII Pin #1 to B-		VII Pin #6 to B-		Th 1A-1B		Th 7A-8B		T3 1-2		T3 3-4	
.52	4.0	1.0	4.8	10.5	11.5	9.4	10.0	.04	1.0	.018	.43

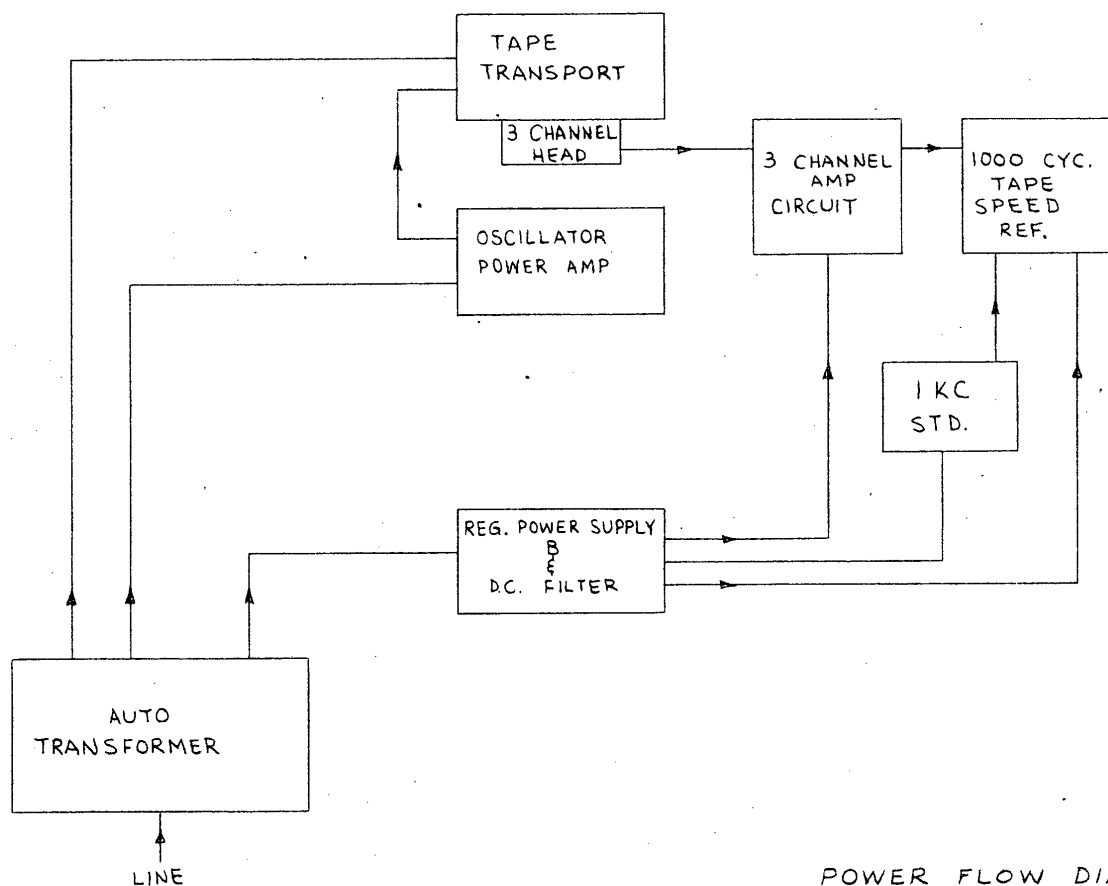
In the event of serious difficulty or damage to this instrument, we strongly suggest that consideration be given to returning it to the factory for repair.



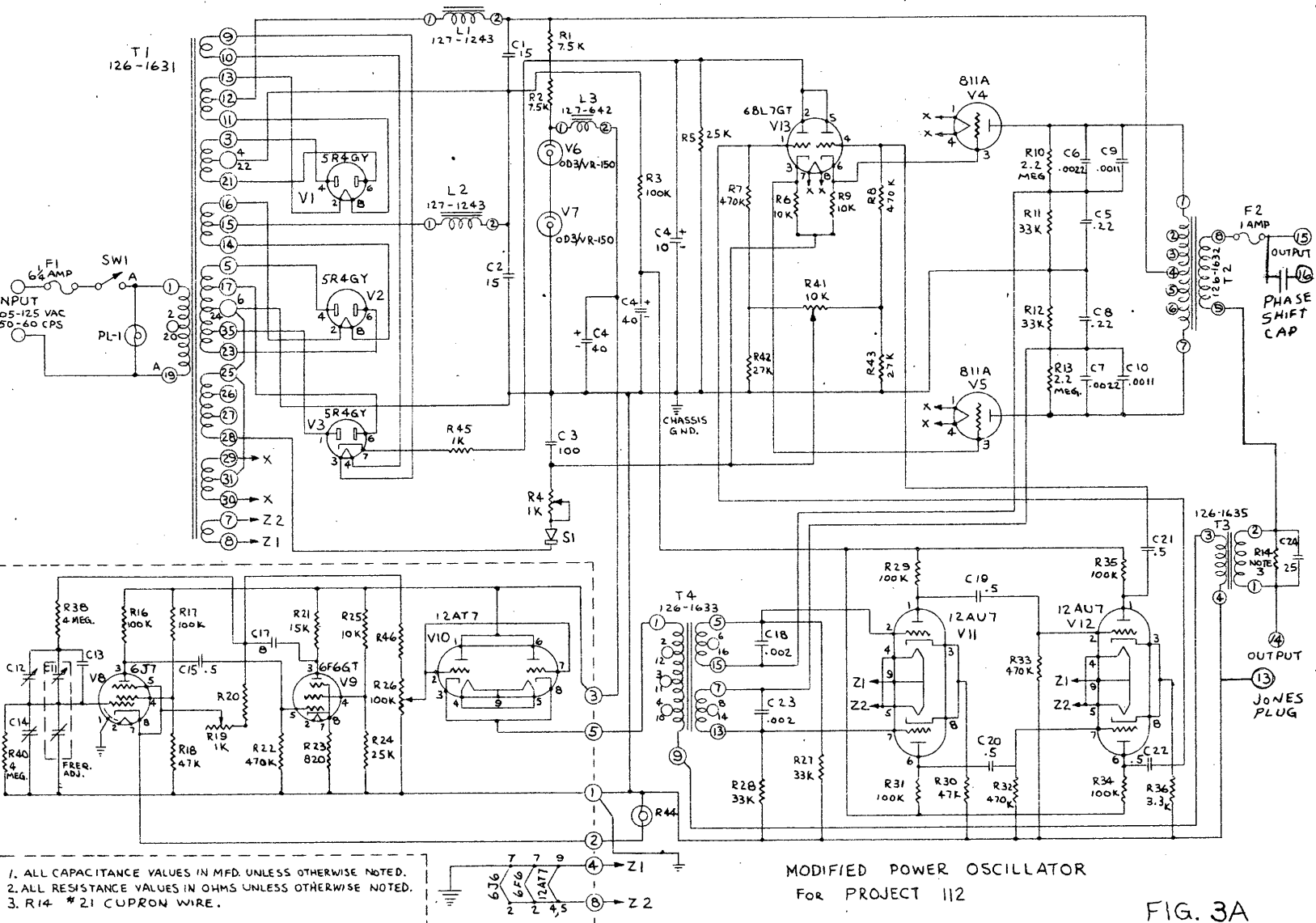


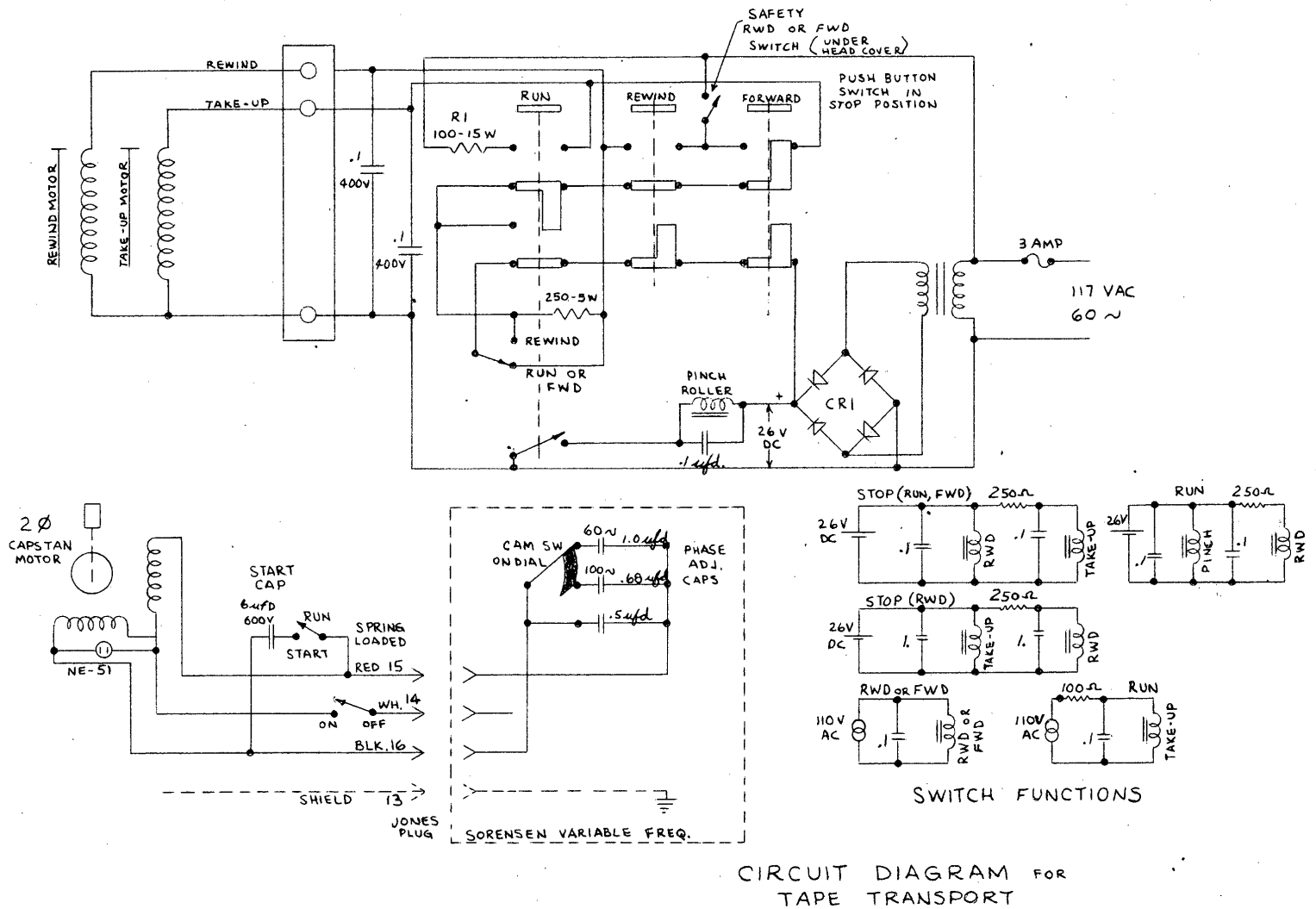


CIRCUIT DIAGRAM OF  
POWER CONNECTIONS



POWER FLOW DIAGRAM  
OF PLAYBACK UNIT





CIRCUIT DIAGRAM FOR TAPE TRANSPORT

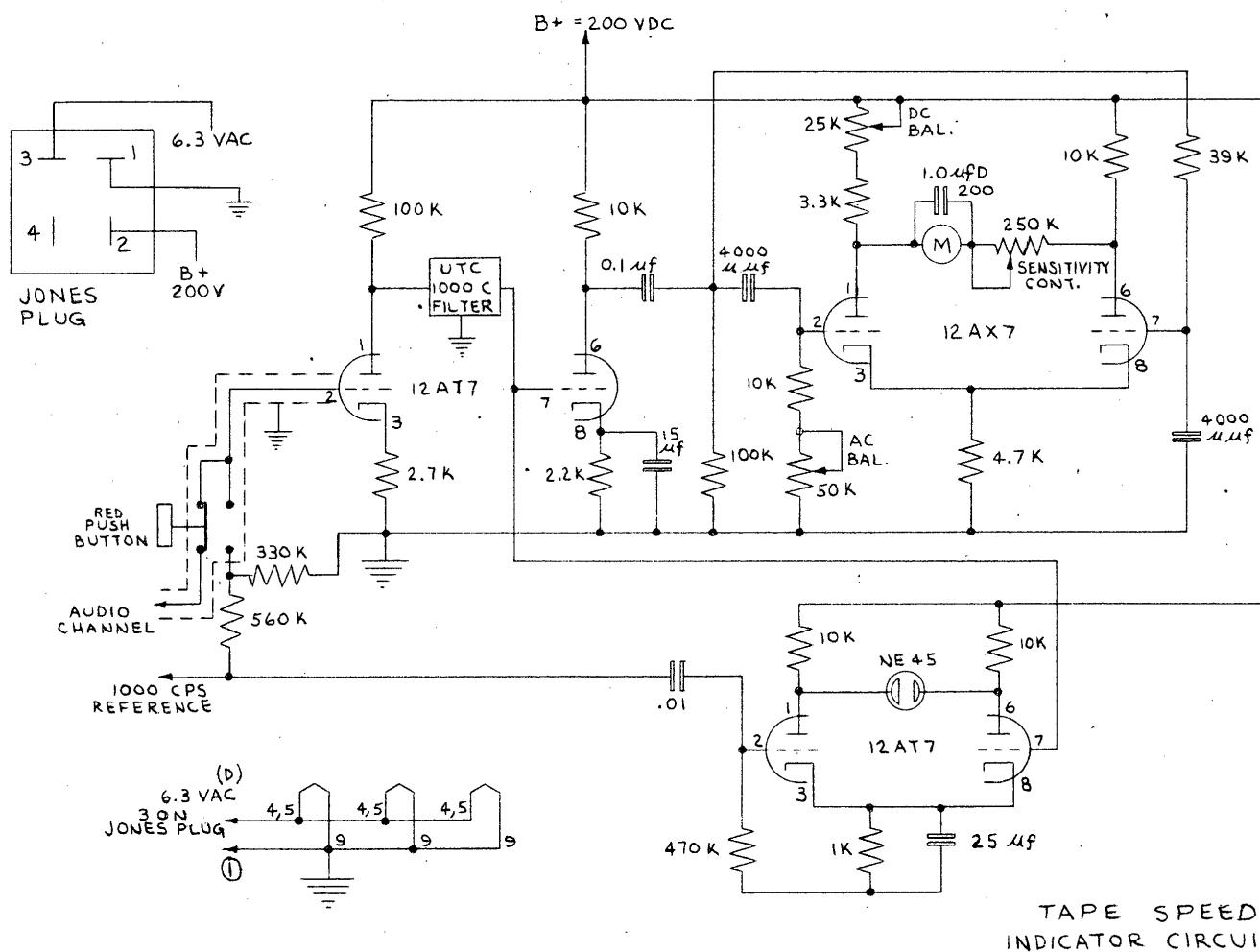
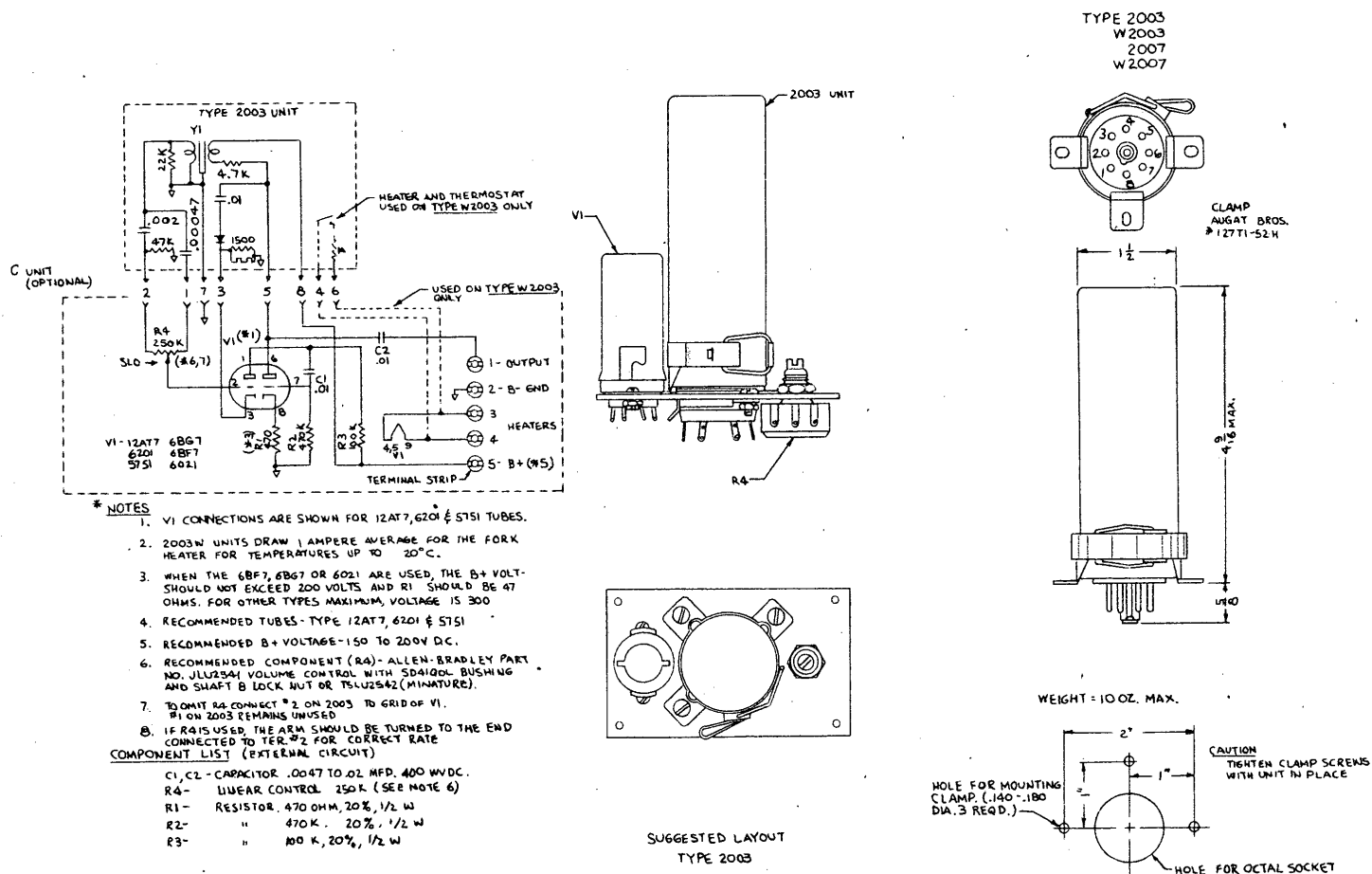


FIG. 5A



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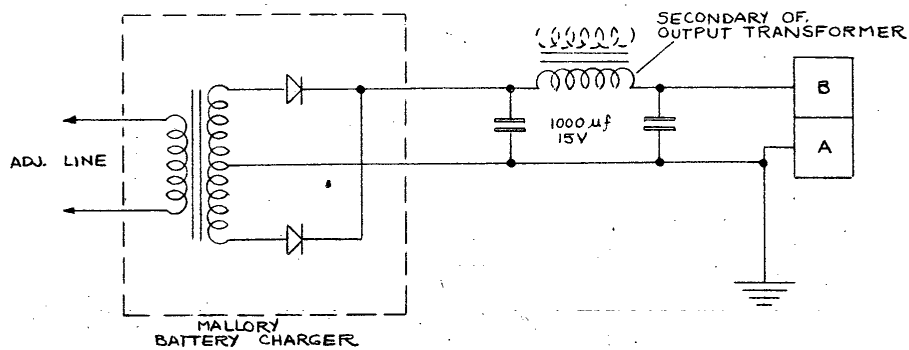
SERIAL NO. 13846 FREQ 1000 CY

CF YAC RT V

FORK NO 36113 CR

SCHEMATIC & LAYOUT  
FOR 2003 SERIES  
960-1000 CYCLES

FIG. 6A



D. C. Filament Supply

Fig. 9A